ECONOMIC BOTANY

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Semi-Popular Articles

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Technical Literature Review

Utilization Abstracts

By the Editor

A Chemurgic Survey of the Desert Flora in the American Southwest

While commercial utilization of the desert flora in the American Southwest is still scarcely begun, there are possibilities of obtaining stock feed, alcohol, paper pulp, sugars, starches, resins, gums, alkaloids, oils and other extractives from the xerophytic plants of the region.

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Introduction

The semi-arid lands of the Southwest stand out as one of the largest undeveloped regions of the United States. There are approximately 100,000 square miles in this area covering Arizona, Nevada, southern New Mexico, and parts of Texas and California. The mean annual rainfall is 15 inches or less. The flora of the region is unique and consists largely of cacti and other xerophytic vegetation which up to the present time have been of little commercial use and serve mainly as a part of the landscape arousing the admiration of passing tourists.

The need for domestic and replenishable sources of many raw materials has been amply emphasized by World War II. It is hoped that this article may serve to extend the horizons of possibilities in this direction, by presenting a survey of past investigations and of work now in progress on the utilization of various plants of the American Southwest and northern Mexico. Attempts to utilize these plants heretofore have been limited, primarily because of the economic factors involved.

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Stock Feed

The utilization of desert plants for stock feed is perhaps the most promising possibility. A large part of the region serves as a grazing range for livestock, especially cattle, and it is not surprising that this field was investigated as early as 1907 (35, 36). At that time cacti were shown to compare favorably with ordinary green fodders and root crops. Ash analysis showed large amounts of calcium, magnesium and potash.

One of the most recent experiments was carried out in 1945 by Valley Vitamins, Inc., a subsidiary of Godfrey L. Cabot, Inc., in their vitamin-A plant at McAllen, Texas. A half-ton of prickly pear cactus was dehydrated and showed a protein content between 7 and 8 per cent. Corn has a protein content of slightly over 10 per cent. According to Mr. L. M. Salmon, manager of the plant, research on the prickly pear will be continued.

Patents have been granted on various methods of processing cacti for stock feed, including incorporation of the crushed plant into cottonseed meal (33) and digestion of the cacti in their own juices to render all parts edible, including the spines (9).

Yucca, too, has been considered as a

stock feed. Analysis yields, on a dry weight basis, 4.4% protein, 6.7% ash, 1.5% fat, 3.2% fiber, 49.2% carbohydrates. Yucca may yield 1,000–2,000 lbs. of green plant per acre (4).

Sarcobatus vermiculatus (Hook.) Torrey, the common greasewood, is undesirable as a stock feed because of its oxalate content, even though no alkaloids, glucosides, saponins, cyanates or similar compounds are present. The oxalates are present as the sodium and potassium salts in the ratio of 4:1 (21).

Alcohol

The various species of cacti contain a large amount of fermentable sugars, or starches and carbohydrates which can be converted to fermentable sugars. Alcohol is obtainable from these sugars by conventional fermentation methods. The cacti are digested in water under slight pressure at 120° to 135° C., the formic acid formed is blown off, and the liquid is fermented with yeast and ammonium phosphate (62, 63). With prickly pear cacti the plant pulp is adjusted to 4%–14% acidity with tartaric acid. After fermentation the crude beer contains about 9.2% ethanol by volume (44).

It is interesting to note that in certain kinds of cacti, ethanol and acetaldehyde are present in the fresh plant in small amounts. Concentration of these increases somewhat in the absence of oxygen (37). Attempts have also been made to hydrolyze mesquite wood (*Prosopis* spp.) fiber for the production of alcohol.

Species of *Agave* have been used many years in the production of a fermented liquor called "pulque". When this liquor is distilled the potent mescal—called "tequila" in some parts of Mexico—is produced. Commercial ethanol production from *Agave* has not been attempted, so far as is known, because pulque and mescal production takes the entire supply of raw material.

Paper and Cellulose

Several of the desert plants, notably yucca (*Yucca* spp.) and sisal, contain long strong cellulose fibers which are excellent for making heavy kraft paper. One such paper, which is commercially available, exhibits unusually high tearing resistance. It is quite resistant to wear and has been used as flashing and weatherstripping material in house construction, and for other uses requiring a tough paper. The fibers have also been used in making burlap and bagging, and those of some species could be used for cordage.

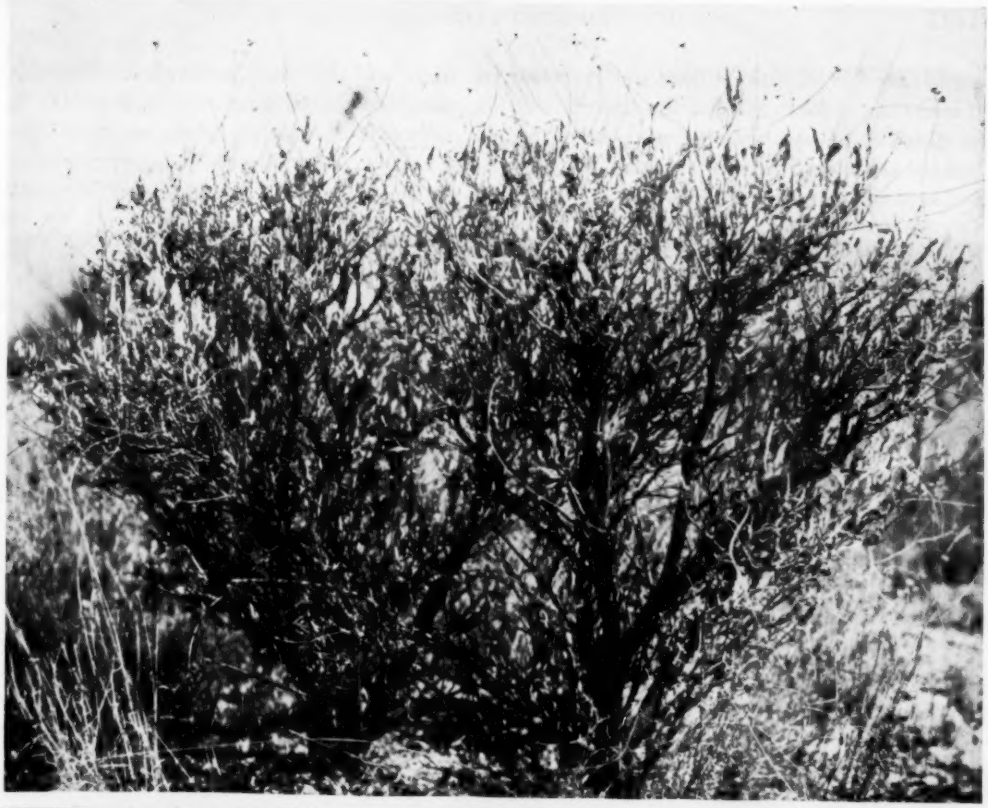
Possibly the most important of these species is *Yucca glauca* Fraser, colloquially known as "bear grass" or "soapweed". A large acreage of this plant grows in the area under consideration. During World War II a considerable amount of it was shipped to a paper mill near the Pacific Coast where the fiber was extracted and made, for the use of the Navy, into the type of paper mentioned above.

In harvesting *Y. glauca* and similar flexible leaved species, such as *Y. elata* Eng., the practically stemless plants are cut at the ground and allowed to dry in the field. This requires about two weeks, after which the plants are gathered somewhat like hay, hauled to a central location and compressed into 300-pound bales which yield over 100 pounds of paper pulp.

It has been found that the fiber from

FIG. 1 (*Upper*). Guayule, *Parthenium argentatum*, one of the recognized secondary sources of rubber that have been exploited to some extent.

FIG. 2 (*Lower*). Prickly pear, *Opuntia Engelmanii*, the flat stems of which offer a possible commercial source of stock feed in the Southwest. The large but poorly flavored edible fruit is rarely eaten, even by the Indians. (*Courtesy of Esther Henderson, Tucson, Arizona*).



rigid-leaved (bayonet) yuccas is over 30 per cent stronger than the fiber from the flexible-leaved species and has but slightly less tensile strength than Manila, the strongest rope fiber. The tensile strength of Manila is rated as 62 kilometers, or about 38 miles, long before it will break under its own weight. In comparison the fiber from species of rigid-leaved yuccas varies from 54 to 61

FIG. 3. *Yucca baccata* in southeastern Arizona. The fibers of this and other species of *Yucca* have been the subject of considerable technical and patent literature in connection with their use in paper-pulp. (*Courtesy of Western Ways*).

kilometers, while that of steel is less than ten. Therefore, for equal weights of material, these natural fibers are approximately six times as strong as steel. However, since steel is more dense, it is stronger for an equal cross section. According to Botkin (13), if the stockpile of Manila fiber had not been large in 1941, the Navy probably would have utilized yucca fiber for rope in addition to their use of the flexible leaf fiber for paper. Although yucca fibers are known to be a desirable raw material, active harvesting programs have been sporadic because only the wild plants have been used. The Government built a $250,000 plant at Kingman, Arizona, to extract the fiber, but production was small and the plant is no longer in operation.

The preparation and use of yucca and similar fibers for paper-making has been the subject of considerable technical and patent literature. The basic process involves digestion of the raw fibers with caustic (57) or caustic and alum (41), washing and drying. Various modifications, especially in the machinery used, are claimed to improve both yield and quality of the fiber obtained (15, 20, 56, 61). Chemical variations include digestion of the fibers in solutions of zinc sulfate (45) and sodium carbonate (19). Much of the work on yucca has been of German origin (19, 20, 67), and there are surveys (11, 53) of the work in Germany. The German yucca fibers appear to be similar to those of the North American plant. The latter has been surveyed in Mexico (23) and in New Mexico (12). The entire subject of the utilization of desert plant fibers has also been reviewed (13).

A small amount of work has been done on the cacti. The Sardinian cactus (*Opuntia ficus-indica* L.), treated with electrolytic alkali hypochlorite at ordinary temperature, gave a completely white and relatively pure lignin-free cellulose with yields of 35%–41%. The alpha-cellulose content was 76%–81% (24). This work was probably done on the entire plant, including both the pulp and the woody skeleton. Apparently some value is placed on the skeleton alone as a source of fiber-like material (1). Reference is made only to the process of loosening the pulp from the skeleton with steam and then removing the pulp mechanically.

Another plant for which potentially new uses might be found is *Nolina Texana* Watson, or "Sacahuiste". This plant, which grows abundantly in parts of New Mexico, is edible but cannot be classed as an important feed. In fact, cattle eat the grass to the ground around *Nolina* clumps, evading the coarse rough leaves of the plant. *Nolina* grows in large bunches. The leaves, which are from two to five feet long and less than one-half inch wide, are high in cellulose and contain about 48% of crude fiber. They have been used in the making of long, rather stiff brooms for street cleaning, and apparently would be satisfactory for baskets and mats. The plants are harvested by cutting at the base, and after drying are tied in bundles with the roots at the same end of the bundle. In this condition, according to Botkin (13), *Nolina* may bring 40 dollars per ton at the baler. Here the ends are trimmed so as to make 18–24-inch lengths before being baled in a broom-corn baler. The native supply is much in excess of the broom requirement, and, since the leaves are high in cellulose, it is hoped that other uses may be found for this material.

Pulp and paper research on mesquite wood is being planned by the Texas Forest Service (45*a*). Studies of first priority will probably involve use of a digester and wet lap machine with the thought that this type of small localized pulp industry will be of most practical application to the region. The wet lap

FIG. 4 (*Upper*). November scene in a mesquite grove of Texas. (*Courtesy of Texas Forest Service*).

FIG. 5 (*Lower*). *Agave* sp. under cultivation in Jalisco, Mexico, for fermentation into the potent beverage pulque which is imbibed as such by the natives or is distilled into equally intoxicating mescal, or tequila. (*Courtesy of Western Ways*).

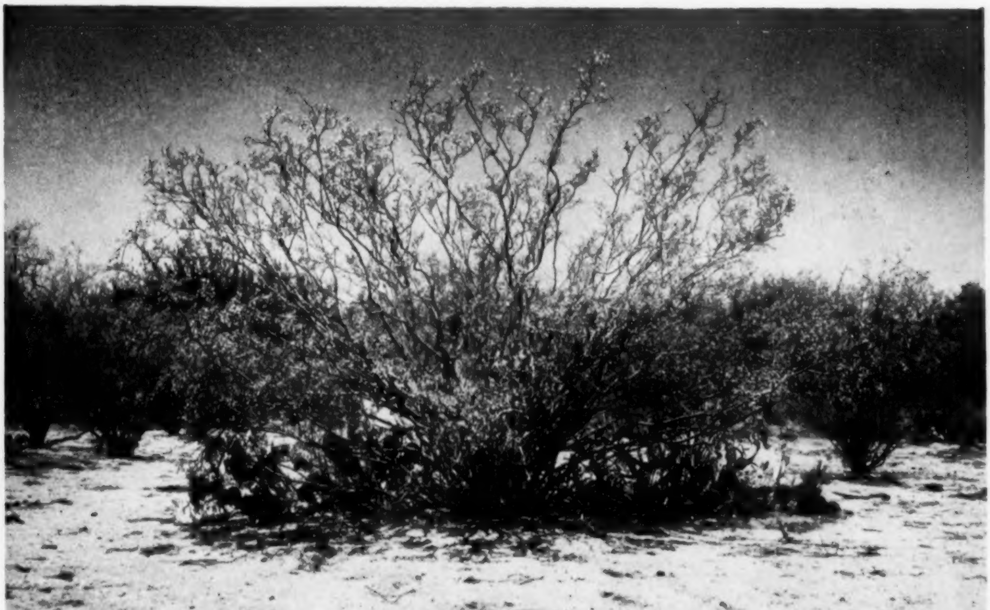


FIG. 6 (*Upper*). Mesquite, *Prosopis juliflora* DC, near Tucson, Arizona. The pods of this and other species of *Prosopis* are used as food by Indians and Mexicans, and gum of commercial value is exuded on the stems. (*Courtesy of Western Ways*).

FIG. 7 (*Lower*). Creosote bush, *Larrea tridentata* (DC) Cov., a possible commercial source of resins. (*Courtesy of Western Ways*).

pulp could then be shipped to a large centrally located mill for fabrication and treatment.

Sugars and Starches

Starches of the type of cornstarch or other domestic grain starches either have not been found or have not been investigated in the various cacti and desert plants. An extended investigation on the gums of mesquite and cholla revealed that *l*-arabinose, *d*-galactose, *l*-rhamnose and glucuronic acids make up the major part of the gum structure (2, 3, 54). Each fraction is capable of being isolated by acid hydrolysis. Fructose, fructosans, dilevans and glucose are present in several species of *Yucca* (26, 55). The beans of the mesquite contain pentosans, galactans and other carbohydrates, while the bean pods are rich in sucrose. Spoehr (60) has presented a summary of the types of sugar in the cacti.

Resins and Gums

Several species of the desert plants under discussion yield resinous gums. In an investigation (3) of mesquite gum emphasis was on the sugars obtainable from the gum, rather than on any use of the gum as such. Diaz (25) distilled mesquite gum and obtained a wax which appears to have possibilities as a replacement or substitute for gum arabic.

Cholla gum from *Opuntia fulgida* Eng., was found to be insoluble in the usual organic solvents, but was soluble in aqueous ammonia or alkali (10). Hydrolysis with 4% aqueous sulfuric acid yielded glucose and pentosans. Other species of *Opuntia*, especially the prickly pear varieties, yield a mucilage which can be used advantageously as an adhesive material in Bordeaux mixture, Paris green and similar sprays in aqueous suspension (29). The performance of DDT and other insecticides might possibly be improved by addition of this mucilage to the spray.

The U. S. Rubber Co. has recently investigated the extraction of resins from the creosote bush (*Larrea tridentata* (DC.) Cov.) at San Simon, Arizona. Several drugstores in the region of Tucson, Arizona, sell mesquite and cholla gum for various uses, but the business is mostly local.

Pharmaceutical Products

"Peyote" is the colloquial name for a group of cacti in the genus *Lophophra*, especially *L. Williamsii* (Lem.) Coult. These grayish-green spineless cacti grow on both banks of the Rio Grande, and in Mexico as far south as Hidalgo. They are rather insignificant in appearance, and the greater part of each plant consists of root. The alkaloids of peyote, or mezcal (mescal), are localized in the internal cells of the cortical parenchyma of the top or crown of the plant. The crowns, cut off and dried, form small discs called "mezcal buttons" which when eaten cause a peculiar type of intoxication; the plant is therefore sometimes called "dry whiskey". One of the alkaloids is capable of producing indescribably beautiful colored hallucinations which occur along with increased respiration, hypertension, muscular incoordination, and in some cases convulsions. No mental disturbances are produced, however.

Havelock Ellis gives the following description of the visions that came to him while under the influence of peyote. "Every color and tone conceivable to me appeared at some time or another. . . . At first there was merely a vague play of light and shade which suggested pictures, but never made them. Then the pictures became more definite, but too confused and crowded to be described, beyond saying that they were of the same general character as the images of the kaleidoscope: symmetrical groupings of spiked objects. Then, in the course of

the evening, they became distinct, but still indescribable—mostly a vast field of golden jewels, studded with red and green stones, ever changing. At the same time, the air around me seemed to be flushed with vague perfume, produc-

FIG. 8. *Opuntia fulgida*, the common cholla of Arizona, from which a gum of possible industrial value can be obtained. (*Courtesy of Esther Henderson, Tucson, Arizona*).

ing with the visions a delicious effect, and all discomfort had vanished except a slight faintness and tremor of the hands".

Intoxication from peyote is singular in that consciousness is never lost, control of the limbs is maintained, a feeling of well-being is experienced, no urge to commit any act of violence is induced, and rarely are there uncomfortable after-effects. The question as to whether peyote is habit-forming is still unsettled, but observations tend to suggest that it is not. The Indians do not use it habitually but only on occasions of ceremony and as a therapeutic agent. They consider it as the greatest of medicines.

When the Spaniards came to Mexico they found that the peyote was worshipped by the natives. In spite of four centuries of civil and religious opposition this worship has not died out in Mexico among the Indians; in fact, circumstances attendant upon the spread of white man's culture throughout North America have made it possible for the peyote religion of Mexico to diffuse in a modified form to more than 30 Indian tribes of the United States.

FIG. 10. The crown of peyote which, when cut off and dried, constitutes "mescal buttons", the alkaloids of which have a molecular structure based on B-phenyl ethylamine. (*Courtesy of Nature Magazine*).

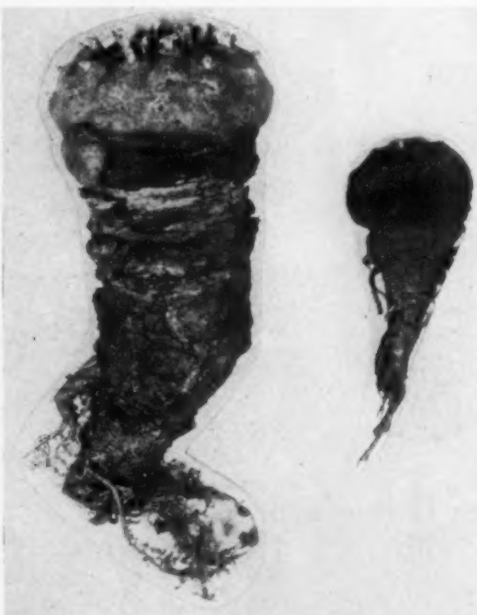


FIG. 9. Peyote, *Lophophora Williamsii* (Lem.) Coult. These small, grayish-green, spineless cacti are mostly root, but their crowns, when cut off and dried, form "mescal buttons" which contain powerful narcotic alkaloids and provide the basis of worship by certain Indian tribes of the Southwest. (*Courtesy of Nature Magazine*).

Many tribes, far removed from the home of peyote, are supplied by merchants on the Rio Grande in Texas, and a large trade has grown up in mezcal buttons. However, no attempt has been made to cultivate peyote, so far as is known, either for its intoxicating effect or for extraction of its alkaloids. Many of these alkaloids have been found to have a molecular structure based on the beta-phenyl ethylamine skeleton. The latter is also the skeleton for the adrenal and sympathomimetic drugs. Spath and his associates (59) at the University of Vienna

extensively investigated the anhalonium alkaloids obtained from a Mexican species of peyote, *Echinocactus Lewinii* Hennings (Syn. *Mammillaria Williamsii* Coulter), and named them anhalamine, anhaline, anhalinine, anhalonidine, anhalonine, lophophorine, mezcaline, N-acetylmezcaline, N-methyl mescaline, O-methyl-d-anhalonidine and pellotine.

Spath's work covered the fundamental research and structure proof of these compounds, but did not offer any applications, medicinally or otherwise. The various isoquinoline structures may be regarded as cylicized N-alkyl-beta phenyl ethyl amine derivatives.

From the Sahuaro cactus (*Cereus* (*Carnegiea*) *gigantea* Enge.) an alkaloid was isolated (38), and Roca obtained three others from the Mexican cactus *Pachycereus marginatus*, (DC) B & R.—cereine, pachycereine, ochoterenine. No further work has been reported on this investigation since Roca's initial paper in 1931. In South America Du Cloux (28) investigated the cactus species *Tricocereus* sp. aff. *T. Terschecki*, and found it to contain an alkaloid having malic acid as the main acid principle, but no phenolic groups, which seem to be so prevalent with the anhalonium-type alkaloids. The fresh plant of *Trichocereus candicans* (Gillies) B & R, containing 95% water, was found to have on this wet basis, 0.05% each of anhaline and a quatenary anhalonium base (49).

The rayless goldenrod (*Aplopappus Hartwigi* (A. Gray) Blake) also contains alkaloids and pyridine (16), but again no use has been found for the extractives.

An unidentified alkaloid, resembling candicine and nicotine in physiological action, has been obtained from *Cereus coryne* Salm-Dyck, a large tree cactus (7). The material was thought possibly to be a dihydroxy phenyl triethyl ammonium compound. By extracting mezcal with 70% alcohol, peyotline, anhalonine and lophophorine are obtained, and can be isolated in the form of these hydrochlorides (64).

The pharmacological properties of cactus alkaloids have been studied by several investigators (*e.g.*, 14, 39, 43). The isoquinoline structure of some of these alkaloids indicates that with some modification of the attached groups, possibilities for antimalarials may exist.

Oils

The field of vegetable oils has been surveyed rather extensively. With the supply still short, new sources of oils have been sought, both for food and for industrial use. From the seeds of a species of *Opuntia*, an oil can be extracted to the extent of 6% by weight (50), the properties of which are listed in Table I. Upon

TABLE I

PROPERTIES OF PRICKLY PEAR SEED OIL

Density	0.9216
Index of Refraction	1.4744
Freezing Point	−10° C
Thermosulfuric Index	65°
Acid No.	5.26
Saponification No.	194.10
Acetyl No.	24.5
Acetyl Saponification No.	210.3
Iodine No.	125.20
Glycerol Assay	9.40%

saponification two acid fractions, one a solid and the other a liquid, were obtained. The properties of the saponified products are listed in Table II. Gourd seeds may also serve as a source of oil which may be hydrogenated into shortening (65). Three wild gourds grow in the Southwest, particularly in the desert, *Cucurbita foetidissima* HBK, *C. palmata* S. Watson, and *C. digitata* A. Gray. The seed of these gourds was used for food by the Indians of the region. The white man adopted such Indian foods as maize, squash, potatoes and beans, but curiously enough seeds from these gourds have been overlooked.

These species are potentially of considerable agricultural and commercial importance for the following reasons: they are perennial and have large fleshy

TABLE II

PROPERTIES OF THE ACID FRACTIONS OF SAPONIFIED PRICKLY PEAR SEED OIL

	Solid Fraction	*Liquid Fraction*
Per Cent of the Total Oil	13.3	73.35
Melting Point	58° C	.....
Freezing Point	50° C	−8° C
Index of Refraction	1.4626 (55° C)	1.4760 (15° C)
Acid No.	13.30	195.30
Iodine No.	18.5	143.40

roots which serve as storage organs for food and moisture; they grow wild on waste lands in regions of low rainfall; they produce an abundant crop of fruit which contains seed rich in oil and protein; the fruit lends itself to mechanical harvesting; and the flesh dries so completely that the seed can be threshed.

Each fruit contains about 12 grams of seed, and, estimating 60 fruits to the plant and approximately 1,200 plants to the acre, an acre could produce 1,800 pounds of seed. From an analysis conducted at the Connecticut Agricultural Experiment Station, the seed of *Cucurbita foetidissima* contained 33.95% fat and 34.22% protein. These calculated yields compare very favorably with other oil- and protein-bearing crops, such as soybeans and peanuts.

No experimentation on these gourds has yet been made in the United States, and it is not known how the oil and the pressed cake containing the protein will compare with other oils and proteins as a food for men and livestock. However, oil from cultivated cucurbits is prized for cooking in the Balkan countries, and squash seeds are relished as food in many parts of the world.

There grows in eastern Mexico, a small tree, *Garcia nutans* Rohr., which bears capsules containing three seeds, each approximately one-half inch in diameter. These seeds analyze about 55 percent oil which has an iodine number of 177 and is superior in some respects to tung oil. Since the stand of the tree is small, test plantings in Texas and Florida have been made to determine the possibilities of the tree on a plantation basis.

Of equal interest is the jojoba (*Simmondsia chinensis* Californica Nuttall), a shrub native to northwestern Mexico and southern Arizona. Although its roasted seeds are eaten by the Indians, and cattle forage for the plant, investigation as to its commercial use is only in an initial stage. The seeds contain approximately 50% of liquid wax, currently a substitute for waxes formerly imported to make shoe polish and other products. Of even more significance are reports that this liquid wax has a constant viscosity over a wide range of temperatures. This is a source of vegetable lubricating oil similar to sperm oil. In yield tests, as much as 14 pounds of seeds have been secured annually from a plant. The adaptability of the species is being tested in Texas. In Arizona 600 acres have been planted by Durkee Famous Foods, a division of the Glidden Company.

Miscellaneous Extractives and Products

Saponin (C_{24} H_{40} O_{14}) has been extracted from the roots of *Yucca filamentosa* Wood (17). The extract has been advertised for sale, and the plants are now being cultivated near Willcox, Arizona, for further exploitation. Saponin has also been obtained from cacti by a process involving the use of diatomaceous earth (48). Canaigre (*Rumex hymenosepalus* Torrey), a member of the dock family, has roots yielding about 25% tannin (4). Tyrosinase of great potency and tyrosine have been found in the Mexican cactus *Pachycereus marginatus* (DC) B & R. (52).

In progress at the present time is an investigation of the various desert plants as sources of odoriferous aldehydes, essential oils and perfume materials. The work is under the direction of T. F. Buehrer of the University of Arizona.

FIG. 11. Sahuara, *Carnegeia gigantea*, the giant tree cactus of the Southwest. The fruit was once used by the Indians for making a palatable syrup to be eaten as such or to be fermented into wine and vinegar. Alkaloids in the plant may have industrial value. (*Courtesy of Esther Henderson, Tucson, Arizona*).

Aldehydes, apparently of an essential oil type, have been obtained by fermentation of cactus pulp and subsequent hydrolysis and distillation (58).

In many parts of the region under consideration the mesquite (*Prosopis juliflora* DC) is a predominant part of the desert flora. It is an aggressive plant, and in the past hundred years, presumably chiefly due to overgrazing and grass fires, has invaded areas as far north as western Oklahoma. Because of its in-

Fig. 12 (*Upper*). Vegetation in the Chisos Mountains of Texas, consisting of prickly pear cactus, *Opuntia* sp.; lechuquilla, *Agave Lecheguilla*; and creosote bush, *Larrea tridentata*. (*Courtesy of the Texas Forest Service*).

Fig. 13 (*Lower*). Mesquite, *Prosopis* sp.; and cedar brush, *Juniperus* sp. along one of the forks of Palo Duro Canyon in Texas. (*Courtesy of the Texas Forest Service*).

vasion of grasslands it has been estimated to cost the ranchers of Texas alone over $30,000,000 each year in lost income (45*a*). Therefore, utilization of mesquite would have a twofold purpose. Present utilization is mainly for fence posts and fuel, and a limited amount of finished lumber and other products has been produced. A small amount of mesquite charcoal is made in Mexico and sold in the United States. However, no large commercial utilization is being practiced, and, although research on uses of mesquite is being conducted, it has not advanced to the point where definite operations can be recommended. Marshall (45*a*) suggests the following possibilities for research on the utilization of the various species: destructive distillation for charcoal, distillate and activated carbon; wood hydrolysis for stock feed, sugars, alcohol and acids; pulp and paper; hydrogenation; tannin extraction; special wood products; plastics; gum; properties and uses of leaves, pods, roots and bark.

The Texas Forest Service Laboratory is studying destructive distillation of mesquite. Preliminary studies on the hydrolysis of mesquite wood have not shown much promise, principally because the wood is relatively low in cellulose content (45 per cent) and because the great amount of inert material absorbs some of the sugar that should be obtained. Mesquite wood yields about 28 gallons of 95 per cent ethyl alcohol per ton of wood. Southern yellow pine, for comparison, yields 49 gallons.

As has been mentioned, pulp and paper research on mesquite wood is to be carried out by the same laboratories.

Hydrogenation of mesquite is another field of research that has not been touched. However, from hydrogenation on other woods it is reasonable to assume that products such as mixed phenols and methyl alcohol might be obtained commercially from mesquite.

The relatively low yield of tannin from mesquite (5%–9% of the heartwood, 5% of the bark) will probably prohibit profitable commercial extraction of tannin in itself. However, if profitable uses could be found for spent chips—such as plastics, wallboard—then commercial production of tannin might prove profitable.

The color and grain of mesquite wood are similar to those of mahogany. The wood is hard, finishes well and has low shrinkage. Its chief disadvantage is its brittleness and the fact that it is oftentimes cross-grained. Its use has been suggested for flooring, paving blocks and cabinet shop products. Paving blocks of mesquite have withstood 25 years of use in a street in San Santonio, Texas (45*a*).

The use of mesquite for plastics seems to hold promise. Mesquite flour has been used as a filler with phenol-formaldehyde resins to produce a desirable plastic. Partial hydrolysis of mesquite with use of the residue for ligno-cellulose plastics is a possibility. The relatively low percentage of cellulose and high percentage of lignin react in favor of mesquite for this type of plastic.

Although mesquite gum has been collected in the past and has been sold locally, no large-scale collection is taking place at present, so far as is known. Its possible use has already been discussed.

A dye (a fustic substitute, algarrobin) has been found in a variety of mesquite, *Prosopis algarrobilla* Griseb. (46). The same author (47) also mentions the occurrence in mesquite of another dye, khaki yellow in color. The wood, bark and pods of mesquite contain tannin in addition to the above dye. The fruit has been analyzed and the seeds found to be rich in protein (6). The seed coats contain pentosans, galactans and other carbohydrates, while the pods are rich in sucrose (66). Although too fibrous to be satisfactorily used as a stock feed, it is

claimed that mesquite bean pods are richer in sucrose than sugar beets. Apparently no thought has been given to the seeds as a source of edible oils.

Rubber

Attempts to use various domestic plants as possible standby sources of natural rubber to replace or supplement hevea latex have been numerous, and some are quite well known. Guayule (*Parthenium argentatum* A. Gray) and goldenrod (*Solidago* spp.) are perhaps the most publicized. Of interest also is the work of the U. S. Rubber Co. in cultivating the vine *Cryptostegia grandiflora* R. Br., indigenous to Madagascar, on a plantation near Yuma, Arizona. From the cactus *Opuntia vulgaris* Miller a latex was obtained which gave an amber-colored gum resembling plantation smoked sheet in color and guayule rubber in properties. The material can replace as much as 20% of smoked sheet rubber in compounding (42). Clark (18) has recently summarized the position of the domestic natural rubbers.

Food

The use of various cactus fruits as food and in food products is interesting, even if of minor commercial importance. Most widely known is the conversion of the barrel cactus fruit (*Ferocactus Wislizeni*) into cactus candy. The fruit of the Sahuaro (*Cereus* (*Carnegiea*) *gigantea* Eng.) was used by the Indians to a considerable extent. From the pulp a palatable syrup was made which was not unlike maple syrup or molasses. The syrup was fermented to make wine and vinegar. The dried pulp resembled dried figs to some extent, and the seeds served as a source of protein (34). Excellent tasty preserves and pickles can be prepared from the fruit of various cacti, after first removing the skin and spines. The leaves of the prickly pear are quite a delicacy—epicures stating that the cooked plant tastes like okra—"the best okra plus a strange, exotic 'something' ". The mucilage of the plant has a laxative action which is recognized by the medical profession (8).

Nordihydroguaiaretic acid, a very effective antioxidant for butter, fats and other food products, is being extracted from the greasewood bush (*Sarcobatus vermiculatus*) on a large scale by the Nordigard Corp., a subsidiary of the William J. Stange Co. The operation is being conducted with the collaboration of the New Mexico Agricultural Experiment Station at Las Cruces. The antioxidant is obtained by extracting the leaves and twigs with an aqueous solution of 5% sodium hydroxide and 2–3% sodium hydrosulfite. The extract is promptly acidified (30). The crude precipitate contains 10%–15% of the acid. The extracted precipitate is taken up in a low-aliphatic ether, and ethylene dichloride is added. The ether and part of the halide are distilled or evaporated until the solution is reduced to a thin syrup. The residual syrup is cooled, and the acid allowed to crystallize. The acid is then filtered and washed with ethylene dichloride (32).

Economic Factors

Many of the raw materials that the desert plants under consideration are

FIG. 14 (*Upper*). The vegetation on part of the desert plain in western Texas, consisting of guayule, *Parthenium argentatum*, an already exploited source of rubber; *Agave Lecheguilla*, the source of tula istle fiber; *Yucca* sp., other sources of fiber; mariola, and creosote bush, *Larrea tridendata*, a possible source of resins. (*Courtesy of the Texas Forest Service*).

FIG. 15 (*Middle*). *Agave* sp.; mesquite, *Prosopis* sp.; sagebrush, *Artemisia* sp.; and greasewood, *Sarcobatus vermiculatus*. Typical of the plains in western Texas. (*Courtesy of the Texas Forest Service*).

FIG. 16 (*Lower*). Creosote bush, *Larrea tridentata*, in Texas. Hen egg Mountain in the distance. (*Courtesy of the Texas Forest Service*).

known to contain, may be obtained from other sources, and frequently at a lower cost. World War II, however, has emphasized the need for further sources of raw materials which could be used in case of a national emergency. For this reason the potential value of the plants of the Southwest should be thoroughly understood so that immediate advantage of the knowledge could be taken, if necessary.

There are a number of economic factors peculiar to the American Southwest which, although not so great as a generation ago, nevertheless serve as a damper on efforts which might be made to utilize some of the products of the desert. These problems differ somewhat, depending on whether or not the desert plants are to be cultivated or utilized in the wild state.

The problem of cultivation of desert plants is one which has been side-stepped in considering the various uses to which the vegetation can be put. There seems to be a difference of opinion as to the feasibility of cultivation. In general, however, the following points may be made:

(*a*) Irrigation would be necessary, unless time were allowed for the plants to grow naturally under the semi-arid conditions of the region.

(*b*) Genetic studies might possibly be necessary. It has been contended that the content of the desired materials, such as alkaloids, might be considerably reduced if attempts are made to hasten growth by heavy irrigation.

(*c*) Individual consideration of each species would have to be given. For example, cultivation of mesquite for gum could probably be handled somewhat like a rubber plantation. Cultivation of some plants, such as Sahuaro for cellulose, undoubtedly would be out of the question, because of their slow growth. On the other hand, a cactus such as the prickly pear might be suitable for this purpose, since in some regions it grows rapidly enough to be classed as a nuisance, and steps have been taken to control it as a weed (22, 27).

(*d*) Frequency of harvest also depends on considerations peculiar to the individual case. For cellulose or fiber, a long and probably continuous harvest would be necessary. On the other hand, if alkaloids or some other product having considerable value were obtained, it might be possible to harvest biennially, or even at longer intervals; if it were necessary that the plants be cut down or uprooted.

(*e*) Transportation is one of the greatest economic problems. Since the region is undeveloped commercially, markets are some distance away, and the haul by railroad is difficult because of the terrain.

(*f*) Labor does not appear to be much of a problem. Before the war peon farm labor was available for $1.50 per day. Under present circumstances, however, this figure has almost certainly increased.

(*g*) Electricity and gas in the Southwest have been readily available, although electricity is now somewhat short because of the abnormally low rainfall combined with increased power demands over the whole area. The Colorado River projects have somewhat alleviated the situation, but at the present time the States involved are in disagreement as to the distribution of both power and water. Water is perhaps the basic problem—the general area of the Southwest has been undergoing a siege of drought for about 16 months. The rainfall in the region of Tucson, Arizona, for example, was about two inches for the year 1947, whereas the mean average over a 40-year period is about ten inches. There was no rain at all in July and August, 1947, while the long-range average for these two months is 4.3 inches. Several irrigation reservoirs have gone dry. The situation is very unusual, but does serve to emphasize the importance of water to the area.

Insofar as power for heat is concerned, an interesting observation may be made here. Gaylor (31) reports that the Russians are using a helioboiler in a fruit cannery near the Indian border. A 1500° F. heat is given, and boiler pressure of 150 psi. is obtained. The sunshine averages 280 days per year there. In the American Southwest the sunshine varies from 300 to 340 days per year. Several private homes have solar hot-water heaters, and the writer can vouch for their effectiveness. It is entirely possible that solar heat could be utilized in projects in the area.

The use of wild plants is, as a whole, undesirable for large-scale works, unless something like the greasewood bush, which is quite plentiful, is used. Even our pine forests require reforestation, and this same consideration applies to desert plants.

Two additional factors are concerned in the case of wild plants. There has been a natural opposition from stockmen to large-scale harvesting of the vegetation on their ranches. Cattle ranches cover a large portion of the territory under discussion, and some sort of working agreement would be necessary before a company harvesting wild plants could begin operations on a large scale. With a narrow margin of profit at best, this might be a limiting factor if too great a financial consideration were necessary.

The flower of the Sahuaro cactus is the State flower of Arizona. Hence these cacti are protected by State law, and the penalty for destroying one without permission is severe. The legal and aesthetic aspects of the destruction of any wild flora, even when replacement by young plants is anticipated, should be carefully investigated.

Summary and Conclusions

It would appear that although chemical utilization of desert plants is not immediately feasible, except perhaps in a few cases, there is considerable promise for future development. The most promising field seems to be that of alkaloids, products from which might be useful in the fields of antimalarials and other pharmaceutical applications. Cultivation of *Yucca* for its fibers, to be used in the manufacture of kraft paper, cardboard and other products, also offers outstanding possibilities for development.

The use of desert plants for production of alcohol, oils, resins, dyes and certain other products, and for utilization on a large scale for stock feed does not seem economically profitable at the present time. However, their potential utilization under changing economic conditions or in time of a national emergency should not be overlooked.

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Utilization Abstract

Jojoba. Seeds of the jojoba bush (*Simmondsia californica*), described in ECONOMIC BOTANY **1**: 401, have been collected by Dr. C. L. Lundell, Director of the Texas State Research Foundation, near Dallas, and distributed through county agricultural agents in 31 south Texas counties to farmers for test planting. This evergreen shrub, closely related to boxwood, is known also as "goat nut" and "pignut", and is native to the semi-arid regions of the American Southwest, extending into Mexico. The "seeds contain 50 per cent liquid wax and can be processed by any cottonseed oil mill. Aside from the wax which can be used in the manufacture of waxes and polishes, the bean has important medicinal agents, is high in protein, and its oil can be used in various food products. It contains a lubricant which has the characteristics of sperm oil, and finally the cake or meal after the wax is extracted can be used for plastics or as an excellent stock feed. Laboratory tests also show the oil to have properties which should make it valuable to the paint and varnish industries". (*Texas Chemurgic News*, as reported in *Chemurgic Digest 7(11): 13. 1948*).

Production, in Venezuela, of Indigenous Varieties of Tobacco

These varieties, still cultivated in a primitive manner, may have value for hybridizing with Burley and Virginia tobaccos. In Venezuela the leaves are manufactured into cigars or are extracted to produce the masticatories known as "chimo" and "tobacco rope".

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During the past year the writer has had opportunity to observe practices used in Venezuela in the production of indigenous, or criollo, varieties of tobacco. From these observations it becomes quite apparent that the commercial methods of cultivating, harvesting, curing and processing the crop there, necessarily very primitive in the beginning, have remained quite unchanged during more than 450 years that have since elapsed. Nevertheless tobaccos of excellent quality and of great demand for cigar manufacture in certain European markets have been produced there year after year for a long period. For the reason that certain of these observations on the handling of native tobaccos are deemed to be of general interest they are recounted at this time.

Historical

Published information regarding the tobacco industry in Venezuela is relatively meagre. The account by Gornes MacPherson (1933) is by far the most comprehensive that has come to hand. Apparently the annual commercial production approximated 36,000 kilos as early as 1607. The crop increased some two hundred years later in the States of Barinas and Portuguesa alone to the extent that the accumulated profits said to have come into the possession of Simon Bolivar, the great liberator, largely provided him with means for prosecuting the war of independence of northern South America. By 1944–1945 the total crop of native tobaccos had increased to over six million kilos. Since that time production of these kinds has sharply declined in favor of rubio (golden or bright colored) tobaccos of the Virginia and Burley types. These milder flavored, lighter-colored kinds, used in cigarette manufacture, even though their cultivation has increased rapidly, are not being grown in sufficient amounts to meet consumer demands in Venezuela.

Native Common Names and Varieties

The difficulties attendant on determining the origin of vernacular names is always intriguing to a biologist. Many names were given by the Indians of tropical America, each tribe applying a different name, to the plant *Nicotiana tabacum* L., now known as "tobacco" throughout the world. This fact is mentioned by Gornes MacPherson. He states that the naturalist von Humboldt

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in 1789 recorded the names used by the peoples whom he encountered while exploring the coastal area of Venezuela from Cumaná westward to Caracas and thence southward across the Cordillera Costanera and the Llanos to the present Territory of Amazonas. Among these names are "azanem", "baniba", "baria", "caribe", "caruzana", "mandauaca", "mapoyo", "maquitare", "mangatu", "piapaco", "piaroa", "punsabe", "sal-libra", "uarao", "urareca", "uajibo" "yabarana", "yabarito" and "yaruro". Similarly a multiplicity of common names is employed at present for many other kinds of plants, especially trees, occurring throughout Venezuela and other parts of Latin America.

At the outset one wishes that more records were available regarding the origin of the varieties that are indigenous to Venezuela and to adjacent countries. Apparently the early Spanish colonists found that the Indians living along the lower reaches of the Orinoco were growing a kind of tobacco that came to be known as "Orinoco". Undoubtedly this is the fundamental variety from which many of the strains of flue-cured tobacco, now grown in southeastern United States, were derived. These early colonists initiated the commercial culture of Orinoco tobacco in the area in which it is indigenous, and it seems probable that they employed, in other parts of Venezuela, other kinds which they found were being grown by the Indians, and which, perhaps, had been grown locally for centuries before the discovery of America.

It is of more than passing interest to note that relatively few varieties of indigenous tobacco now occur in Venezuela. Undoubtedly this is traceable to the fact that there have been no technologists in that country interested in improving the crop by selection and by hybridization. Each Venezuelan variety is well established and has long been known in each particular region. For example, there occurs in the State of Sucre in the region bordering the Golfo de Cariaco and extending eastward to Carúpano and El Pilár, an extensively-grown variety known as "Golfero". In the States of Barinas and Portuguesa, the variety Barinas, which is well known throughout the world, is widely grown, and in the States of Falcón and Lara, with the town of Cabudare as a marketing center, the variety Cabudare.

In addition there are Salóm, grown in the State of Carabobo in the environs of the town of Solóm; Cocorote, in the State of Yaracuy, near Cocorote; Guácharo, in the State of Monagras, in the vicinity of Caripe; Guanaguana, Cumanacoa, San António de Maturín, and Tranco Corto, in the region around Guanape in the State of Auzoátegui. Such other varieties as Chimó, Commún and Mundo Nuevo are also planted, each one usually in a different region.

Seed Beds or "Almacigos"

As with seedbeds everywhere, the essential features for their proper preparation concern selection of a suitable site and preparation of the soil. In general, well drained sites on uncultivated land are chosen, such as may be found near the base of a hill or mountain, or on a slope near a stream. The natural vegetation of such places usually consists of shrubs and trees. By means of "el machete" (large knife) and "la escardilla" (hoe) the seedbed site is cleared and the soil loosened to a depth of three or four inches. In so doing the leaf mold and decaying leaves are thoroughly incorporated in the loosened soil. The seed are then sown, usually during August which occurs near the middle of the rainy season. Very little seedbed care, such as weeding and watering, is required, and the seedlings will be of sufficient size for transplanting early in October. Losses in the seed-

beds from damping-off diseases ("san-cocho") are inconsequential.

Such seedbed practices, because of their simplicity, are markedly different from those used in growing Virginia and Burley types in Venezuela. For such types, by use of plows and shovels, the surface of the beds is elevated ten to 20 centimeters or more above the surrounding terrain to secure adequate drainage and to prevent flooding. Then a cover is provided to protect against

FIG. 1 (*Upper*). A caney of the kind commonly used for air-curing indigenous kinds of tobacco in Venezuela.

FIG. 2 (*Lower*). Cultivating tobacco in Venezuela with a special implement pulled by an ox (buey).

torrential rains and intense sunlight. These covers are constructed of pole frames with a roof of a grass, known as "gamelote" (*Panicum maximum* Jacq.), or of banana or palm leaves. The covers must be removed and replaced daily to permit suitable illumination, and the beds must be watered frequently. Under these conditions damping-off, induced by species of *Pythium*, *Rhizoctonia* and *Sclerotinia*, may cause such severe losses as to be a limiting factor in the production of seedlings.

The causes for differences in incidence of damping-off in seedbeds for these different types of tobacco remain unknown. But since each grower of native tobacco raises from 1,000 to 50,000 plants only, his seedbeds are small. On the other hand, those who grow Virginia and Burley types may plant areas varying in extent from ten to 100 hectares, and hence each farmer requires large seedbeds. The growing of a large population of seedlings in a restricted area, as must be done with Virginia and Burley types, may favor significantly the incidence of damping-off. It seems more likely, however, that the difference in disease incidence is attributable primarily to difference in degree of disturbance of microbial balance in the soils during preparation of the seedbeds. Observations indicate that antibiosis in the control of soil-borne pathogenic fungi is a significant factor, at least to the extent that it is worthy of consideration in proper seedbed preparation and management.

Field Practices

Mountain sides, even those having a declivity of as much as 75 per cent, are sometimes cleared and planted to tobacco, but the more nearly level valley lands, which are of alluvial origin, are generally used. Such soils have long been known to be the most suitable for tobacco production (3). In fact in one valley a farmer when asked how long tobacco had been grown there responded "Yo lo creo que el tabaco ha sido crecido aquí después el principio del mundo" (I believe that tobacco has been grown here ever since the beginning of the world).

For the most part, each farm ("hacienda") comprises from one to fifty thousand hectares on which tobacco is cultivated in small parcels. The landowner ("latisfundista") and the tenant or small grower ("conuquero") arrange terms for the cultivation of each small tract. The basis of terms may be a share of the crop or a fixed price per kilo of cured tobacco. Not uncommonly also the terms include credit for supplies of food and clothing for the grower and his family. Sometimes such credit is advanced by a merchant, especially if he is also a tobacco dealer.

In many instances the escardilla and machete are the only implements available for use in preparing and cultivating the fields, but sometimes, by arrangement with the landowner, ox-drawn or tractor-drawn plows and disc harrows are used for this purpose. The field is not laid off in ridged rows in preparation for transplanting, as is done with Virginia varieties in the United States, but is kept quite plane. Commercial fertilizers are not used at all. The seedlings may be transplanted in rows a meter or more apart or may be interplanted in the middle of rows of nearly mature corn. In the latter event, the weeds and grass must first be removed with a hoe, and the seedlings are transplanted near the center of these small cleared patches. Essentially all subsequent cultivation is done with a hoe, the weeds are kept cut off, and by the time the dry season has begun, a layer of loose soil has been formed which provides a mulch and helps to conserve soil moisture.

Harvesting and Processing

All native tobaccos are harvested by picking the leaves a few at a time as they mature, beginning with the lowermost and progressing toward the top of the plant. The length of the harvesting period depends upon two things, the topping practices and the rains. Plants are generally topped as soon as the inflorescences are of sufficient size to be grasped by the finger tips and broken off. Suckers ("chupones") then develop, and each of them, too, may be topped early. If the tops are removed from all suckers as soon as they appear, the plants will continue to vegetate, and, provided rainfall is adequate, each plant may produce from 50 to more than 100 sucker leaves, all of which are harvested. Under such conditions there may be four pickings of main leaves, and five or six pickings of sucker leaves during a period of six to eight months. In rare instances the main stems are cut off immediately after harvest, new shoots are then permitted to develop, and when their leaves are harvested, the stems are again cut off. By so doing repeatedly, and by avoiding flowering and fruiting, the plants continue to vegetate for a year or even for several years. The leaves borne on the primary stems constitute the main crop ("cosecha principál"), and all other leaves are "los ratoñes".

The tobaccos are mostly air-cured, but some may be sun-cured. For air-curing, shelters ("caneyes") are used, which are constructed of poles lashed together with bark fibers ("majágua"), and the roof is thatched, usually with gamelote. The racks for sun-curing are built of poles and are placed at convenient points in the field. When the leaves are almost cured they are transferred to a shelter to complete the curing and to store them.

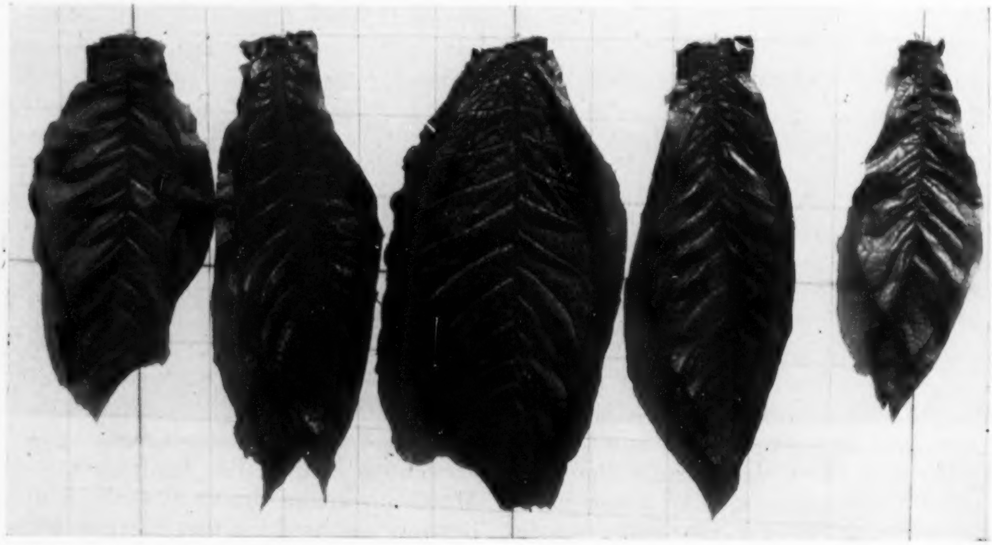

FIG. 3. Leaves of five native Venezuelan varieties of tobacco. Leaf size is shown by the 10 cm². square grid in the background. From left to right the varieties are Salóm, Cocorote, Chimó, Tranco Corto, Guácharo.

In preparation for curing, the leaves are fastened to ropes ("cuerdas") made of bark fibers. This is done by enmeshing bundles of leaves while the fibers are being braided into ropes.

The strings of leaves thus formed are then hung, hammock-like, in the caney, the length of the string being conditioned by the caney's length.

As soon as the leaves are cured, and at times when they have absorbed sufficient moisture to be handled without breakage, they are graded in preparation for being taken to market. Leaf size is a most important feature in grading. Size is determined by grasping the base of the leaf by the fingers, and the leaf tip is then extended up the arm. Those leaves having a length to extend from the finger-tips to the elbow are of one grade, those not so long are of another grade, and all longer ones are in third grade.

There is no price discrimination between los ratoñes and la cosecha principál. Sometimes rains adversely affect the quality of the latter, however, and it is not uncommon that the ratoñes are the more desirable because they are the heavier-bodied and the more aromatic. After being graded and tied into hands, the tobaccos, whether in possession of the grower or dealer, are arranged in piles, whereupon they undergo fermentation. During fermentation the light-brown and yellow-brown colors of carefully cured leaves change to become considerably darker, and the characteristic cigar aroma is developed.

Uses of Tobacco Other Than in the Manufacture of Cigars

A large proportion of this kind of tobacco is ultimately used, either abroad or locally, in the manufacture of cigars, but a part is always utilized in making two other products, "chimó" and "tobacco rope" ("cuerda del macho o burro", "tabaco al masticar").

Chimó is a thick, tarry, dark paste, prepared by extracting the ripened leaves and the suckers in caldrons of boiling water. The extractive is then evaporated until the residue has a very thick consistency, whereupon it is placed in barrels and marketed. The buyer then puts it into jars or other suitable containers, or small lumps of it are wrapped in waxed papers for sale to consumers. Those who use chimó hold it in their mouth in quite the same way as is done by those who dip snuff.

Tobacco rope is a form of chewing tobacco. It is prepared by extracting the leaves, as is done in making chimó, but the extractive is afterward absorbed by the boiled leaves and applied to them. This is done by dipping the leaves in the extractive while they are being twisted tightly into ropes. The ropes are next air-dried. Then at the time of sale to the consumer or user these ropes are cut into the desired lengths.

Characteristics of the Leaves of Certain Indigenous Varieties

To learn more about the features of certain of the native tobaccos than is possible from field observations in Venezuela, seeds were gathered and were used to grow plants at the Tobacco Experiment Station, Oxford, N. C., during the summer of 1948. The examinations made of these varieties included determination of the population of glandular hairs and leaf size by methods described in a previous study (1). Certain of these data are summarized in Table 1.

These five varieties evidently belong in two quite distinct groups. Chimó is definitely in a group with cigar-filler tobaccos, not too unlike kinds being grown in Pennsylvania and Wisconsin. The other four are all closely related and have the appearance of flue-cured varieties, especially such kinds as Lizard's Tail, Little Orinoco, Warne and Adcock which were popular among growers of flue-cured tobacco a generation ago. The leaves of Guácharo are the smallest and narrowest. All four varieties have a similar per unit-area population of glandular hairs and all

are very aromatic. In fact their per unit-area hair population is essentially the same as that of the most aromatic of the 80 or more varieties of Turkish tobacco that the writer has examined (1, 4).

It seems probable that environment has induced an increase in hairiness of Venezuelan varieties during the several hundred years of commercial cultivation. The natural infertility of the soils and the non-use of commercial fertilizers have caused slow plant growth. Extended periods of paucity of soil moisture and intense illumination have also exerted an influence unfavorable for rapid growth. No doubt, too, such plants as were most tolerant of these conditions year after year have served as sources of seed for each succeeding crop, and thus the net result has been increased resistance to drought and increased hairiness with a correlated increased volume of aroma.

TABLE 1

SOME LEAF CHARACTERS OF VENEZUELAN VARIETIES OF TOBACCO

Varietal name	*Number of leaves per plant*	*Average number of hairs per cm²*	*Average leaf area, cm²*	*Average hair population per leaf in thousands*
Chimó	24–25	1146	1341.3	1537.9
Guácharo	23–27	1740	490.6	852.3
Tranco Corto	19–21	1606	654.2	1262.4
Salóm	26–35	1525	731.4	1126.3
Concorote	24–28	1758	816.3	1271.4

Leaves from each of the five varieties, when grown at Oxford, N. C., were harvested, and some from each picking were then air-cured; others were flue-cured. When air-cured their color and texture were like those of Burley tobacco. Indeed it was the opinion of expert tobacconists that they constituted very acceptable Burley tobacco. When flue-cured, however, the tobacco was yellow-brown, papery and of such poor quality as not to be particularly desirable as flue-cured tobacco. In any event these varieties can not be expected to compete successfully where excellent varieties of Virginia and Burley are already established.

General Considerations

It should be borne in mind that native Venezuelan varieties of tobacco grow slowly, are late maturing, and their leaves have a dense population of glandular hairs. After several years of study by the writer and his associates it was determined that such features in Turkish varieties of tobacco are correlated with desirable "quality". It should be added that the determination of what constitutes desirable features of Turkish tobacco and of how to grow a crop having desirable quality required several years of painstaking effort, whereas, in contrast, tobaccos with such characteristics have been developed in Venezuela without any purposeful efforts, without knowledge of developments in tobacco technology in other parts of the world, and without the intervention of scientists. Moreover, each Venezuelan variety has a high degree of uniformity. In fact, they are so uniform that their production would reflect credit to anyone having a background of knowledge of the principles of hybridization and selection.

It remains to be demonstrated that any of the Venezuelan kinds will prove valuable as stocks for hybridization with Virginia and Burley varieties, to be grown in the United States, but such use is indicated as a means of securing resistance to drought and to diseases. In the writer's opinion, if more care were given the leaves during curing and subsequent storage in Venezuela, the

resultant tobacco should be acceptable in the manufacture of bright-colored cigarettes.

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Utilization Abstract

Yerba maté. "Yerba maté or yerba de maté, also known as Paraguay-tea, is a plant whose leaves are prized in South America for beverage making. This beverage is similar in taste and chemical composition to tea and likewise has a stimulating and refreshing effect on the drinker. The tree is a kinsman of the holly and grows from Bolivia and Mato Grosso, Brazil, to northern Uruguay and the Argentine Province of Corrientes. The beverage is most commonly made from the leaves of the species *Ilex paraguariensis*.

"The yerba maté tree prefers ravines or depressions in the foothills and mountains at elevations of from 1,500 to 2,500 feet, a damp humid climate, and deep, alluvial soil containing large amounts of humus. The Paraná pine is usually a close neighbor in the forest, sometimes providing shade for the yerba maté tree. Brazil is the principal producer of maté, followed by Argentina and Paraguay. Most of Brazil's maté production comes from wild forests, where the trees sometimes grow to a height of 80 or 100 feet. When grown on plantations, the trees are usually pruned and range from 12 to 30 feet in height.

"Harvesting begins when the tree is 4 or 5 years old and is carried on from May to October when the leaves are dry. Leaves are gathered from the same trees preferably not oftener than every second or third year. Workers cut the small branches, toast the leaves evenly by holding the branches over a bonfire, and then place them in a barbacuá or ovenlike structure for drying. The mass of branches and leaves is stirred frequently during the 4- or 5-hour drying process, after which it is taken to the threshing floor. After the leaves are separated from branches and other waste material, they are finely ground, sifted, and graded.

"Maté has not yet gained popularity outside South America. That imported into the United States in 1947, for example, totaled only 21,000 pounds, compared with 67,448,000 pounds of tea and 2,500,000,000 of coffee. It is a "must" item, however, in the daily diet of many of our neighbors in Argentina, Brazil, Paraguay, and, to a less extent, in Uruguay and Chile. Prewar production of maté amounted to 368,000,000 pounds, approximately one-fourth as much as the world tea output". (*Foreign Agriculture 12(5): 111. 1948*).

9

The "Palo de Tomate" or Tree Tomato

Widely known throughout the tropics of the world but not abundantly cultivated outside its native Andean home, this fruit offers a desirable addition to the food resources of warmer climates.

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Cyphomandra betacea (Cav.) Sendt., "Palo de tomate", "Tomate de arbol" or tree tomato, is generally considered a native of Peru. It is abundantly cultivated and highly esteemed in many parts of the inter-Andean region where it is one of the most popular fruits. Although not commonly known, it is grown in many parts of the world. In the warmer sections, such as Malaya and the Philippines, it is successfully cultivated only at higher elevations, for it grows poorly and seldom fruits in the hot tropical lowlands. In Ecuador it is grown between 5,000 and 10,000 feet. In cooler climates cultivation is possible down to sea level.

In Puerto Rico the plants grow best in the mountain section, but satisfactory growth has been observed near Rio Piedras at an elevation of less than 100 feet. In the Toro Negro Unit of the Caribbean National Forest and in a number of other hill sections, from 1,000 to 3,000 feet elevation, the plants produce fruit without benefit of cultivation.

The tree tomato as it grows in Puerto Rico is a woody shrub sometimes approaching the size of a small tree, 12 to 18 feet tall and two to four inches in diameter near the soil surface. Exceptional plants may reach a height of 25 feet. At higher elevations the plants are smaller. The cordate, ovate leaves are three to 12 inches long. The lavender pink flowers, half to three quarter inch in diameter, are borne in small, axillary cymes near the ends of branches and appear at the beginning of the rainy season, usually in April or May. The two-carpeled fruits are red to orange, the size and general shape of a hen's egg but more pointed. They ripen in October and remain on the trees until January.

The culture of tree tomatoes has probably been most extensive in the Far East where purple varieties are also grown. It is commonly grown in the hill-country gardens of Ceylon where it fruits almost throughout the year, but chiefly from March to May. The tree is a quick grower, commencing to bear when one and a half to two years old and becoming unproductive after five to six years. It comes into bearing earlier from cuttings, but seeds are also satisfactory.

The succulent, subacid fruit is generally considered to taste like a tomato. However, some believe it is also similar to gooseberry and passion fruit. When cooked the flavor suggests apricots. It has a rather distinct and pleasant aftertaste. In fact a flavor differential exists. The meaty mesocarp, or flesh just inside the skin, has a bland cheesy flavor, while a watery, slightly acid, but sweet pulp surrounds the seeds. The fruit may be broken open and eaten raw. Some people do not consider them so satisfying as better known fruits, but others regard them as refreshing and agreeable. A more common method is to stew the fruits to form a conserve or "dulce".

The skin is tougher than in the cultivated tomato and has a disagreeable flavor. It should be removed before cooking. This is easily accomplished after immersing the fruit in boiling water for a minute or two. While garden tomato seeds can usually be included in the final product, the seed of the tree tomato should be removed from the pulp because they are harder than those of the tomato and bitter in taste. The pulp can be passed through a coarse strainer before cooking with sugar. The resulting preserve can be improved by addition of cinnamon and salt.

The tree tomato can also be used in curries, mixed vegetable dishes, soups, and for most of the uses of the garden tomato.

The tree tomatoes are popular in their original home and many other sections of the world. The hill country residents of Puerto Rico usually cook them without removal of the skin and seeds. Since this factor is of sufficient importance to make the difference between a desirable and an undesirable fruit, it is easy to understand why they are not more widely used.

The tree tomato should not be con-

FIG. 1. The fruits of the tree tomato are produced in small loose clusters hanging near the ends of branches.

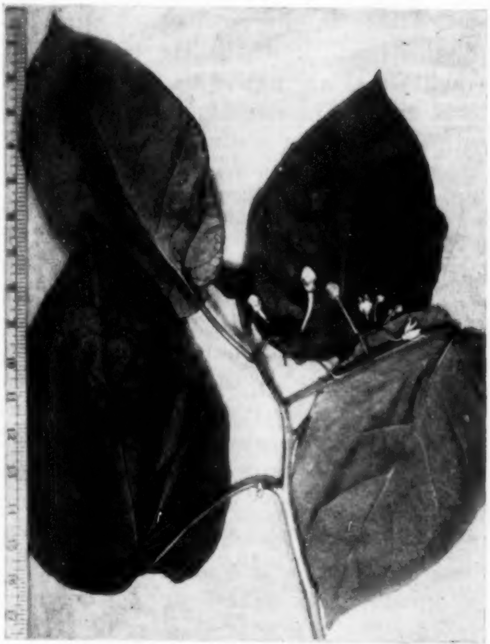

FIG. 2. The lavender or lavender pink flowers are $\frac{1}{2}$ to $\frac{3}{4}$ inch in diameter and resemble those of a tomato.

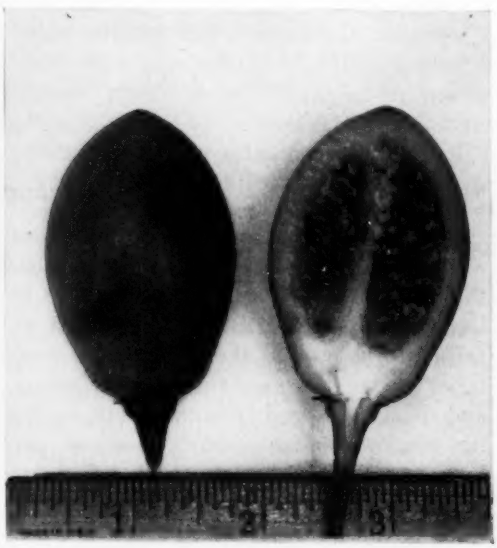

FIG. 3. The tree-tomato fruit has two locules containing seeds somewhat larger than those of the cultivated tomato.

fused with the naranjilla, *Solanum quitoense* Lam. Both belong to the same family and are native to the same general area. The densely pubescent fruit of the naranjilla is nearly spherical, and its purplish leaves are long and usually spiny. Its chief use is as a juice or "jugo".

The tree tomato has received little attention from plant breeders. It is quite possible that it is as good as or better than the garden tomato was before extensive breeding work on the latter was begun. It is also possible that by selection and hybridization this fruit might be similarly improved. Francis O. Holmes of the Rockefeller Institute for Medical Research at Princeton, New Jersey, has shown that this is one of the only two hosts of all he has tested which was resistant to the virus of tobacco mosaic.

This crop appears to have considerable value for those living in tropical highlands because of its resistance to insects and diseases and its ability to grow with little or no culture, even in high rainfall areas. Culture would undoubtedly result in greater yields. An additional advantage is that the fruits mature at a season when few fresh vegetable products are available. A few plants in the home garden could add considerable to the family diet. Also, the tomato which it resembles does not thrive at higher altitudes where the tree tomato is best adapted. A limited export trade might be developed with this specialty fruit.

Utilization Abstract

Chlorophyll. Commercial production of chlorophyll is expected to begin sometime this year in a new extracting plant to be located in Rockford, Ill. In this plant alfalfa will be used as the principal raw material during the northern growing season, and spinach, shipped from the South, during the winter. The chlorophyll produced will be used for medical purposes, since it is believed by the sponsors of this project that chlorophyll, extracted in its natural form, can be administered to prevent or correct either an overactive or underactive metabolism and will have beneficial effects in the treatment of arteriosclerosis, hypertension, heart disease and fatigues. (*Chemurgic Digest 8(3): 16. 1949*).

This chlorophyll-extraction work, which was reported in ECONOMIC BOTANY **2**: 362. 1948, has been developed by Dr. Boris Berkman and his sister, Dr. Sophia Berkman, both of Chicago. The former directed the Government-sponsored extraction of milkweed floss during World War II, and an article by him on that work will appear in the next issue of ECONOMIC BOTANY.

Safflower*

A potential oilseed crop in the western States

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Introduction

SAFFLOWER is an oilseed crop which for many years has been grown on a relatively small scale in parts of North Africa and the Middle East. Its production in Egypt dates back some 3,500 years, as indicated by seeds found in the graves of Pharaohs (8). In very early times it was cultivated primarily as a source of red dye (carthamin) obtained from the flowers and secondarily as a source of oil obtained from the seed. At the present time it is grown in foreign countries only as a source of oil or grain which is commonly fed to poultry and livestock.

During the period of 1925 to 1935 a number of Agricultural Experiment Stations and farmers in the Midwest and western States made trial plantings of safflower in cooperation with the U. S. Department of Agriculture. The results of these tests were summarized by Rabak in 1935 (6). He concluded that safflower offered some possibilities as a dry land and irrigated oilseed crop in the northern Great Plains and western States. The varieties tested were of Russian origin and contained only 22 to 26 per cent oil. Interest in safflower from 1935 until the beginning of World War II generally declined. Many States discontinued all tests with this crop. However, during this period a few varieties with 28 to 31 per cent oil were introduced from India and Turkestan by the U. S. Department of Agriculture and by Mr. Alfred Rehbein, Sr., a Montana farmer.

In 1941 the Nebraska State Legislature established the Chemurgy Project at the University of Nebraska. One of the functions of the project was to determine the feasibility of producing new crops which could be used industrially in Nebraska. Safflower was one of those considered in this category. In 1942, the first year of agronomic tests, many varieties of safflower which were then available in this country were grown at eight locations in the State. From production tests in western Nebraska that year and the results of previous tests by several Agricultural Experiment Stations, the crop was thought to show sufficient promise to merit the establishment of an extensive breeding program in this State. As a result of this work a variety which averages 34 per cent oil is now available for increase. The purpose of this article is to stimulate interest in safflower as a source of oil and meal in areas where it is adapted; to present recent data on varietal and cultural tests; to discuss some of the accomplishments and possibilities in breeding for higher oil content; and to present the current status of commercial production in the United States.

Characteristics and Adaptation

Safflower, *Carthamus tinctorius* L., belongs to the Compositae, subfamily Cynareae, commonly known as the thistle family. It is a much branched, herbaceous annual. All branches are terminated by an individual head composed of 20 to 80 florets. Each floret may produce one seed. It attains a height of 16 to 48 inches, depending upon variety and

* Reprinted from Chemurgic Digest 7 (3): 11. 1948, except statistics and other details of experimentation.

moisture conditions. From the farmer's viewpoint safflower has both good and bad characteristics. Good features are that it does not shatter, is not subject to bird damage and does not lodge. Undesirable characteristics are spininess of present varieties, susceptibility to grasshoppers and slow growth in early spring which contributes toward poor weed competition. By breeding it is possible to largely eliminate these undesirable features.

Safflower is adapted to areas which have dry atmospheric conditions from time of flower bud formation until after maturity. Low relative humidity is essential for good seed-set and high oil content. The area of adaptation is thus limited to regions which have arid or semi-arid climates during the latter part of the growing season. In the United States safflower is adapted to the western part of the northern Great Plains and that part of the Pacific Northwest located between the Cascade and Rocky Mountains. In order to mature in this area, the growing season must be at least 120 days. It may also be adapted to parts of southwestern United States as a fall planted crop. The crop is apparently not adapted to the corn belt, or to eastern or southern United States.

For the past several years safflower seed of the more promising introductions and selections has been sent by the Chemurgy Project of the University of Nebraska to a number of Agricultural Experiment Stations in other States for regional uniform testing. Results from these tests are now showing where safflower is best adapted and whether this crop can compete with existing crops in areas where it is adapted.

Utilization of Oil and Meal

The oil content of existing safflower varieties varies from 19 to 34 per cent. Several lots of seed have been successfully processed by an expeller unit in the Nebraska Chemurgy Laboratory. Results of these tests have been published (10). Safflower produces a drying oil which is characterized by high linoleic acid content (approximately 75 per cent) and very low linolenic acid content (0 to trace). The iodine value of the oil ranges from 140 to 150 (1). Without the addition of driers, the rate of thickening of safflower oil is slower than that of linseed oil, particularly during the initial stages. In the presence of driers safflower oil dries as fast as linseed oil (5). In India the oil is utilized mostly for culinary purposes (7). The seed and oil produced in foreign countries is for the most part consumed locally and seldom enters world trade.

Carrick and Nielsen (1) studied the possibilities of safflower oil as a vehicle in protective coatings. They concluded that safflower oil would be satisfactory as a vehicle in outside paints, inside enamels, as a source of heat-treated oils of high linoleic acid content and in the preparation of alkyd resins. Pugsley and Winter (5) concluded that, "Safflower oil could replace linseed oil in most organic coating compositions, and in some instances improved coatings would be obtained". It therefore seems likely that safflower oil in the United States may find more profitable utilization in the paint, varnish and allied industries than as an edible oil.

The Department of Animal Husbandry of the University of Nebraska compared safflower meal containing a crude protein content of approximately 42 per cent with soybean meal for wintering calves and for fattening yearling steers. The Scottsbluff Substation compared the same oilseed meals for fattening lambs. Daily gains in all three feeding tests were slightly higher with the safflower meal (9). The crude protein content of safflower meal may vary from 20 to 55 per cent, depending upon variety, protein content of whole seed, and the percentage of hulls removed previous to processing. More experi-

mental data are needed to determine the proper percentage of hulls to be removed for best processing and feeding results.

Varietal Experiments

Kupzow (4) has made an extensive study of the geographical variability of safflower. He found that there were distinct geographical types. Introductions made by the Nebraska Chemurgy Project from a number of countries of North Africa and the Middle East confirm Kupzow's findings. There apparently has not been a great deal of interchange of safflower varieties between countries of the Middle East and North Africa. Evolutionary changes in this crop have obviously been progressing at several secondary centers of origin. Complete spinelessness has been found only in introductions of the Afghanistan type. North Africa has been the best source of high oil content varieties. According to Kupzow's (4) detailed descriptions of safflower from different geographical areas, there are apparently many types in existence which have not yet been introduced into this country. Introductions and selections developed by the Nebraska Chemurgy Project breeding program have been compared for yield, oil content and other characteristics.

Safflower plots in rows ten inches apart (solid drilled) were planted at the rate of 30 pounds per acre, and plots in cultivated rows 40 inches apart were planted at the rate of 15 pounds per acre. There were no significant differences in yield between row spacings. Flowering commenced approximately two days earlier and maturity occurred seven to ten days earlier in solid drilled plots than in cultivated rows. Nebraska 852 yielded significantly higher than all other varieties. The interaction between varieties and row spacings was significant. A planting rate of 30 pounds per acre in solid drilling for Afghanistan types may be too heavy for maximum yields.

A comparison of test weight and oil content in the seven safflower varieties planted shows that high oil content is not related to high test weight. Test weight is a characteristic of geographical types and does not necessarily indicate oil content. Introductions from Africa grown in Nebraska vary in test weight from 38 to 45 pounds per bushel. Hindustan and Russian introductions are high in test weight, 42 to 49 pounds per bushel. The Russian varieties are exceptionally high in test weight and low in oil content. Afghanistan types are intermediate in test weight, 40 to 47 pounds per bushel.

Limited data indicate that there may be a positive correlation between test weight and oil content within the same variety. Irrigation seems to lower both test weight and oil content of all varieties. In the purchase of seed by industry the variety should be taken into account before placing any emphasis on test weight. Varieties can often be recognized by seed characteristics. For example, N-852 seed can easily be recognized from Indian safflower by the longer and narrower seed shape. The hull on N-852 also has more pronounced ridges than Indian.

Since the uses of safflower oil appear to be similar to those of linseed, it is important to determine the relative yielding ability of the two crops. Data on the comparative yields of these crops during a four-year period on fallowed and nonfallowed land in western Nebraska indicate that safflower yields on the average 20 to 25 per cent more pounds of seed per acre than flax. The margin of safflower over flax is the highest when soil moisture conditions are favorable. Under droughty conditions on non-fallowed land flax usually yields as much as or more than does safflower. Under irrigation safflower often yields 50 to 75 per cent more seed per acre than flax.

Since flax matures approximately one

month earlier than safflower, flax escapes the effects of droughts which occur during the later part of the growing season. More data are needed on the comparative yielding ability of these two crops grown under the variable climatic conditions of the western States.

Cultural Experiments

One phase of the safflower research program in Nebraska has been to determine the most satisfactory production practices. Experimental results from 1942 to 1944, inclusive, have been published (3). Some of the more pertinent data on production practices obtained during the past three years are presented in the original publication of this article in the Chemurgic Digest.

Breeding for Higher Oil Content

An important part of the safflower breeding program has been to develop varieties with high oil and low hull content. During the past few years some 500 to 700 oil and hull analyses were made each year on seed from individual plants selected from the better introductions. These analyses have shown that there is a strong negative relationship between oil and hull content. Seed which contains a high percentage of oil will contain a low percentage of hull. The oil content of seed introduced from North Africa and the Middle East has varied from 22 to 34 per cent. Seed from most introductions contained less than 30 per cent oil and more than 50 per cent hull.

Most introductions are not pure for oil content. For example, single plant reselections from the Special Russian variety vary in oil content from 17 to 38 per cent, and in hull content from 35 to 64 per cent. The Special Russian variety averages approximately 29 per cent oil.

A number of individual plants originally selected from varieties of three distinct types contain from 37 to 39 per cent oil. By reselecting in the progeny of these plants, it should be possible to purify lines that will average 36 to 37 per cent oil within several years. In order to increase oil and reduce hull content still further, crosses are now being made between high oil content plants of distinct types.

Present Status of Commercial Production

During the 1930's farmers in Montana grew a few thousand acres of safflower of the Russian varieties. As previously stated, these varieties contained only 22 to 26 per cent oil. The few quotations made by industry for safflower of that oil content were not high enough to encourage production.

During the past four years, 8 to 20 farmers located in western Nebraska have been growing several hundred acres of Indian safflower each year. In 1946 Cargill, Inc., became interested in promoting and processing safflower. As a result of this interest, in 1947 there were approximately 4,000 acres grown. This acreage was centered in southeastern Montana. Seed produced on this acreage which was not kept for 1948 planting was purchased by Cargill, Inc., for 75 per cent of the prevailing flaxseed price on a poundage basis. Approximately 1,200,000 pounds of seed were processed. A production of 15,000 acres of safflower was estimated for 1948. This acreage was widely scattered in Montana, Nebraska, Washington, Idaho, Oregon and North Dakota.

Indian safflower has been the only variety grown during the past four years. Seed from this variety averages 28 to 30 per cent in oil. Although it is very impure, most plants are spiny. Orange is the predominant flower color. At the present time it is the only variety available in quantity for commercial production.

Nebraska 852, an introduction from the Anglo-Egyptian Sudan, is now in the

process of being increased for commercial planting. It is reasonably uniform for type but is not pure for flower color. The predominant flower color is yellow. This variety averages 34 per cent oil. It is distinctly different from Indian, is superior in yield and rapid growth early in the season. N-852 is more susceptible to grasshoppers than Indian. A total of 3,500 pounds of

Fig. 1 (*Upper*). African Sudan type of safflower.
Fig. 2 (*Lower*). Field plots of safflower planted in solid drilling and in 40-inch rows at Alliance, Neb., 1947.

N-852 was released to Nebraska farmers and to a few Agricultural Experiment Stations in the western States for planting in 1948.

Nebraska 55, a selection made in 1943 from Pusa 14, is being increased in Oregon. This selection is similar in appearance and yield to Indian. Its chief advantage over Indian is that it has 1 to $1\frac{1}{2}$ per cent more oil. It is uniform for type and is pure orange flowered. In 1947 a total of 5,500 pounds of Nebraska 55 seed was produced in northeast Oregon.

A number of other Nebraska selections have been increased to a few pounds. Some of these selections are spineless and contain 29 to 30 per cent oil. These will be tested for yield during the next several years and may be released later.

Recommendations for Seed Increase

During the past four years some difficulty has been encountered in maintaining pure safflower seed of good quality. Small grain and some weeds such as wild sunflowers are difficult and in some cases impossible to separate from safflower seed with the usual type of seed cleaner. In order to maintain pure seed supplies the following suggestions are made: (*a*) Safflower for seed increase should be planted on summer fallowed land. If this is not possible, it should follow some crop other than small grain or safflower. (*b*) Planting should be in cultivated rows 36 to 42 inches apart so that the field can be rogued if necessary. It is easier to rogue if not more than five to eight pounds of seed per acre are planted. The best time to rogue safflower is immediately after the last cultivation which normally occurs during the latter part of June or the forepart of July. The spines are not so objectionable then as they are later in the year. (*c*) Since safflower is cross-pollinated from 5 to 100 per cent by insects (2), seed increase fields should be isolated from other safflower varieties at least 40 rods and preferably considerably farther. (*d*) Harvesting should be done soon after maturity so that germination will not be reduced by fall rains.

Harvesting

Because of spines on the leaves of most varieties now available for commercial production, combine harvesting is essential. Since the crop does not shatter or lodge, harvesting can be delayed two to four weeks after maturity, if necessary, to fit other labor needs on the farm. Delayed harvesting is not advisable if seed is to be used for planting. In order to prevent cracking the seed, it is essential to reduce cylinder speed to approximately 500 r.p.m. Proper wind and sieve adjustments of combine will remove practically all leaves, stem parts and unfilled seeds. There is usually a low percentage of unfilled seed in all safflower grown.

Conclusions

In the past safflower has been an oilseed crop of only minor importance. It appears now that this crop can be sufficiently improved by breeding so that in the near future it may be of considerable economic importance in western United States. Experimental data on safflower oil indicate that it would be satisfactory in the paint, varnish and allied industries. Feeding experiments with the oilseed meal from decorticated (hulled) seed show that it is at least equal to soybean meal in feeding value.

Data presented on production practices show that safflower in western Nebraska should be planted between April 10 and May 5. Planting can be either in solid drilling, as in wheat, or in cultivated rows. In solid drilling, safflower competes with weeds better than does flax but not so well as do the

small grains. There is wide variation in satisfactory planting rates.

Nebraska 852, an introduction from the Anglo-Egyptian Sudan, is the best variety now available for production. New varieties are, however, being developed at the University of Nebraska which will be superior in yield and oil content to Nebraska 852. These should be available for planting within a few years.

Since the oil content in safflower seed is so variable (19 to 38 per cent), the oil percentage of the variety considered for commercial production will have a direct bearing on the price which can be paid for the seed. Varieties which average less than 28 per cent oil should not be considered for this purpose. As soon as varieties which average 34 or more per cent oil are available, it seems probable that safflower will find a permanent place in the agriculture of a number of western States. The production of safflower would add another cash crop to areas which are predominantly cropped to wheat. This may be of value should an overproduction of wheat occur. Safflower production in this area would also add a valuable oilseed meal to the adjacent range land.

Now that a commercial market for safflower seed has been established, considerable encouragement has been given to the expansion of production in the western States.

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Utilization Abstract

Drug Plants of Africa. This is the title of a 125-page booklet by Thomas S. Githens, M.D., published by the University of Pennsylvania Press as African Handbook No. 8 of the University Museum. In addition to introductory chapters on the chemical basis and utilization of drug plants it lists by common names, scientific names, geographical sources and uses over 1400 species of plants under the following categories: Plant Drugs Exported, Generic Synonyms, Chemical Basis of Drug Action, and Utilization of Plant Drugs.

Cinchona Cultivation in Guatemala—
A Brief Historical Review up to 1943

The first American planting of cinchona was in 1860 in Guatemala and Jamaica. Subsequent investments in Guatemala by private and governmental agencies, negligible until stimulated by the recent war, have culminated today in plantations aggregating only about 1,000 acres with 1 3/4 million trees.

WILSON POPENOE

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Introduction

At first glance it seems remarkable that two hundred years should have elapsed between the discovery of cinchona (about 1630) and its adoption as a cultivated plant. But this is not so strange when we pause to recall that cinchona, in its more valuable forms, is not an easy tree to cultivate, and that there were ample supplies of wild bark to meet demands in Europe and America.

It was not until the British and Dutch undertook the development of the Asiatic tropics that the necessity for bringing cinchona into cultivation became apparent. Throughout the Indies malaria was a scourge affecting millions of people. Serious-minded investigators who visited the cinchona forests of the Andes returned to Europe stating that the supply of wild bark was dwindling, the trees in danger of complete extermination.

In 1813 Dr. Ainslie bemoaned the fact that India did not grow her own cinchona bark, a sentiment reiterated by Dr. Royce in 1835; and in Java the botanists Fritze, Miquel and others urged the introduction of the tree into that island.

The Dutch were the first to take action, but the British were not far behind. The year that Hasskarl left for the Andes (1852), efforts were made to get the British government to send out an expedition. These did not bear fruit until 1859 when Clements R. Markham was instructed to organise an exploration of all important cinchona-producing regions and bring to India planting material—seeds and young trees—of as many promising forms as possible. Thus began one of the most dramatic and important series of events in the entire history of plant introduction. The work was successful; but it remained for Charles Ledger, an Englishman living in Upper Perú (now Bolivia), to lay the foundations of the modern cinchona industry in the Far East by obtaining seeds of a superior strain from the region of Coroico in 1865.

Cinchona in Jamaica

Markham did not limit his program to India; he included Jamaica. So far as we have been able to ascertain, this was the beginning of cinchona cultivation in the American tropics. In his classic work, "Peruvian Bark" (London, 1880), Markham states that the first seeds were sent to Jamaica in 1860 and planted on the Blue Mountains near

Bath. About 1868 a further supply of seeds was sent to that island from Ceylon. The later history—and ultimate failure—of cinchona planting in Jamaica need not be recounted here.

First Attempts in Guatemala

Though Markham sent seeds to Mexico, where they were planted near Córdoba in 1872, nothing came of the effort; and we can turn our attention to Guatemala, the only tropical American country where serious attempts were made to grow cinchona in these early days.

Emili Pilli, who brought together in 1942 much documentary material regarding the history of cinchona culture in this Republic, states that Julio Rossignon was the first to plant the tree here. The date is given as 1860, the location near Cobán. Rossignon is known also for having been the first to send seeds of teosinte (*Euchlaena*) to Europe. Pilli states that Rossignon's cinchona trees received little attention and finally disappeared.

The first serious attempt to grow cinchona commercially in Guatemala seems to have been that of the Sarg family, of which we have reliable details in the memoirs of Franz Sarg, "Deutschtum in der Alta Verapaz", 1938.

Our chief interest in those early plantings is to trace the origin of the seeds employed, since it is from these seeds that many of the trees growing in the Republic have descended. Sarg states definitely that the stock used by his family was obtained from Ceylon through the good offices of Prince Nikolaus of Nassau, and that the year was 1878.

In this same year the Minister of Agriculture, Manuel Herrera, addressed a lengthy memorandum to President Justo Rufino Barrios, pointing out the advantages of cinchona cultivation and urging that the government take steps to foster the introduction and establishment of cinchona trees. In 1878 President Barrios issued a decree sponsoring the project, and offered prizes to those who would make plantings. Under the terms of this decree, the Sarg brothers received in 1882 the sum of $1,500 for their planting of 2,200 trees, which at that time were two years or more of age. Pilli states that the Alcalde of Cobán, who had these trees examined, reported that they were of two species, *Calisaya* and *succirubra.*

In connection with the taxonomy of *Cinchona,* not only in the early days but right down to the present time, the greatest caution must be exercised. Early studies suggested, and more recent investigations have amply demonstrated, that cinchonas in the wild are subject to such extreme variation—and there are so many hybrids—that specific names may mean very little.

The next step of importance seems to have been taken by the government of Guatemala which in 1883 contracted the services of W. J. Forsyth, an Englishman who had worked with cinchona in the Asiatic tropics. Under the terms of his contract, Mr. Forsyth went to Ceylon and brought back seeds with which nurseries were established in a number of places. Since the succirubras which were obtained by Richard Spruce on the slopes of Chimborazo in Ecuador were at that time being cultivated extensively in Ceylon and India, it is reasonable to believe that much of the Forsyth stock was of that strain, an assumption borne out by the appearance and the alkaloid-pattern of many trees now in Guatemala which originated in, or have descended from, the Forsyth introductions.

Pilli presents some interesting figures, as of 1884, regarding the location and extent of the Forsyth plantings. These data are of value to us in connection with the history of the material with

which we are working today. Of particular importance is the planting at Finca El Porvenir, made under the direction of President Justo Rufino Barrios, who was the owner of the property and who rightfully may be called the father of cinchona cultivation in Guatemala. This honor, however, should perhaps be shared with others—notably the Sarg brothers of Coban, and Don Manuel Herrera, Minister of Agriculture.

After the death of Barrios the Reformer, cinchona culture entered a period of decline due to several factors, some of which can with difficulty be evaluated at this late day. Colombia was shipping large quantities of wild bark, much of it better in quality than that being grown in Guatemala; Java was coming into production with its fine Ledgeriana barks; prices were falling in world markets; and coffee was King.

The Beginnings of a New Era

Throughout the 1890's and the first three decades of the 1900's, cinchona cultivation in Guatemala was in the doldrums. Many of the trees which had been planted for shade in coffee fincas were destroyed. Experimental shipments of bark which were occasionally made to the United States and Europe usually resulted in loss—or at best no satisfactory profit—to the growers. The preponderance of succirubra blood in practically all of the Guatemalan trees rendered impossible any competition with Ledgeriana barks from Java.

During the first World War a serious situation developed with regard to supplies of quinine needed by the Allies. In subsequent years it was realized that an effort must be made to achieve independence of the Far East with regard to this important product.

The genesis of this effort is set forth by Frederic Rosengarten, Jr., in his "History of the Cinchona Project of Merck and Co. Inc., and Experimental Plantations Inc., 1934–1943", from which I quote the following paragraph:

"In early 1932 Merck and Co. Inc. considered the advisability of developing Cinchona in the Western Hemisphere, at the suggestion of, and in cooperation with, the State Department of the United States. It was deemed expedient to build up supplies of cinchona bark in the Americas in order to become independent of the Dutch Quinine Monopoly. It was logical that Merck and Co. Inc. should have been keenly interested in bringing cinchona cultivation back to the Americas, in view of the fact that this Company, through its predecessors, had maintained an unbroken interest in the extraction of quinine from cinchona barks since 1822, when Farr and Kunzi commenced the operation of a quinine factory in Philadelphia, two years subsequent to the isolation and identification of quinine as a crystalline compound by the French chemists Pelletier and Caventou".

After a brief and unsuccessful attempt to establish cinchona in the southern United States, Guatemala was chosen as the base for experimental work. Some of the arguments in favor of this country were the following: (*a*) it is nearer the United States than the cinchona regions of the Andes; (*b*) its government was favorably disposed toward projects of this sort; (*c*) experience of the previous century gave grounds for believing soil and climate were suitable; and (*d*) there were present in Guatemala considerable numbers of intelligent, progressive coffee planters, prepared to cooperate in the work with energy and determination.

Col. Victor E. Ruehl was delegated by Merck and Co. Inc. to undertake the organization and development of the project. He came to Guatemala in the

spring of 1934 with a supply of Ledgeriana seed which had been purchased in Java. His first act was to establish close contact with the Director of Agriculture, Don Mariano Pacheco H., a man peculiarly fitted to assist because of his keen interest in new crops and his unusual ability as a plantsman.

Col. Ruehl travelled widely over the Republic, seeking out what appeared to be favorable sites for experimental plantings. He was warmly received by the finqueros (coffee planters), and shortly entered into arrangements with the late Gordon Smith of Finca Mocá near Guatalón; L. Lind Pettersen of Finca Zapote, Escuintla; Pedro G. Cofiño of Finca Retana, Antigua; and Gustavo Helmrich of Finca Samac, Cobán.

At that time, Guatemalan agriculturists had no experience with Ledgerianas—except at Finca El Porvenir where Dr. Goebel had planted a few trees. Everyone had to start from scratch. Col. Ruehl's first need was for nurserymen to propagate and grow the Java stock. He obtained from the United Fruit Company two young men trained at Lancetilla Experiment Station in Honduras: Jorge Benítez, an Ecuadorian; and Hans Franke, a German. These men were put in charge of nursery work, cooperating with the finqueros mentioned, who furnished all facilities.

Seedbeds were established at Retana, in Antigua; at Finca El Zapote; at Finca Mocá; and at Finca Samac near Cobán. In addition, some of the Java seed was left at Washington to be propagated in the greenhouses of the United States Department of Agriculture, and some was given to Don Mariano Pacheco. A small quantity was sent to Lancetilla Experiment Station in Honduras but failed to grow at that low elevation.

The seedbeds at Retana were a failure. We have since learned that Ledgeriana is not suited to that location—perhaps in part because of climate, in part because the soil is not sufficiently acid. The first plantings made at Zapote also failed because the seeds were killed, it is believed, by formalin treatment aimed to prevent the development of disease. A stand was obtained at Mocá, but it was soon observed that the plants were not doing well, and the stock was removed, in the main, to Finca Helvetia, also under the direction of Gordon Smith. Gustavo Helmrich at Coban, working alone, grew some plants and established what was, until destroyed by floods in October, 1940, one of the best plantations in Guatemala. Fortunately, before these trees were lost, many of them were propagated by grafting as well as by seed.

Don Mariano Pacheco grew a fine stock of plants which were later distributed to various places. B. Y. Morrison of the U. S. Department of Agriculture sent to Guatemala not only many plants grown from the Ruehl seed, but many others grown from seed obtained from the Philippines; from Amani, Africa; and elsewhere. Seeds from old trees near Cobán, at Helvetia, and other places in Guatemala were also planted in various nurseries.

The Kinds of Material

Before proceeding further it becomes necessary to discuss briefly the kinds of cinchonas with which we are dealing. The subject is almost hopeless if we adhere to a purely botanical classification. Ever since Weddell's time (the 1840's), the botany of the genus *Cinchona* has baffled every student. The best-known kind of cinchona, Ledgeriana, is itself so variable, and has been subject to so much crossing with other forms, that it is hard to say just what constitutes a Ledgeriana tree and what does not. Sir Frank Stockdale, in his report on cinchona culture in Java (1938), writes:

"Survivors of the original planting are still to be seen on the estate and it is clear that the seed was heterozygous as in the population raised from it many variations in habit of growth, leaf and bark characteristics are to be noticed". And elsewhere it has been stated that among these original trees, grown from Mr. Ledger's Bolivian seed, there is a range in quinine sulfate content from 3% to 13%.

And again, the wild form of *C. pubescens* or succirubra in Costa Rica contains practically no quinine; while the wild form from the slopes of Chimborazo in Ecuador (from which it is probable that most of the succirubras in cultivation have been derived) sometimes contains as much as 5%. It is therefore obvious that the agriculturist must devote little attention to the botanical classification of the material with which he works and much to its characteristics of growth and its economic value. This is made even more obligatory by the fact that much of the material in cultivation is undoubtedly the result of hybridization, often between a known pistillate and an unknown staminate parent.

At the same time, we must take notice of the botanical classification of our cinchonas because there are characteristic differences in what may be termed the alkaloid pattern of these wild forms. Thus, the Calisayas normally show a preponderance of quinine over the other principal alkaloids—cinchonine, cinchonidine and quinidine; while the succirubras do not have this preponderance; and the micranthas typically show almost no quinine at all.

Early efforts to split the genus into many species which do not always come true from seed proved hopeless from the standpoint of the practical agriculturist, as they have proved to be from that of the sound botanist. The tendency now is to recognize only a few well-defined species and admit that within each of them there are many forms of varying economic value.

In the early days of cinchona exploitation in the Andes the wild forms acquired common or trade names, and it may be well for us to follow these in part. Sir Clements Markham listed the principal wild sources of commercial bark as follows:

C. Calisaya (Bolivia and Peru) Yellow Bark or Calisaya.

C. succirubra (now called *C. pubescens*) Ecuador, etc. Red Bark.

C. micrantha (Ecuador and Peru) Gray Bark.

C. officinalis (Colombia and Ecuador) Crown Bark.

C. Pitayensis (Colombia and Ecuador) Colombian or Pitayo Bark.

Of the above species, one of the most recent students of the genus, Paul C. Standley of Chicago, recognizes only *C. officinalis, C. pubescens, C. micrantha* and *C. pitayensis,* including the Calisayas or Yellow Barks in *C. officinalis.* Certain other botanists, however, do not agree in this. The divergence of opinion is of little importance, compared with the discrepancy between some of the earlier classifications, which made 30 to 40 species of the above, and the present simplified outlook.

The Work in Guatemala Continues

The Ledgerianas planted in Guatemala in 1934 from Java seed showed many variations from the start; nevertheless there could be recognized a narrow-leaved form which was considered to be the type and which in general showed the highest content of quinine. At Finca El Zapote these narrow-leaved forms (which had come from the Washington stock, shipped down after the original seed failed to germinate in Guatemala) promptly began to die out, while the broader-leaved forms survived in small numbers and have given rise to

a group of plants, considered to be hybrids, which are of strong growth and good quinine content, though not so high as some of the narrow-leaved Ledgerianas. L. Lind Pettersen took up with energy the study and propagation of these forms, and they are generally considered, at the present writing, to be some of the most promising in all Guatemala for commercial cultivation.

At Finca Mocá a few Ledgerianas which were planted in the field have done fairly well; but most of the stock which, as has been mentioned, was removed to Helvetia has done much better; and Helvetia at present has the largest planting in Guatemala of the narrow-leaved Ledgeriana forms. From Helvetia plantings were made at Finca Patzulín where also the narrow-leaved forms have done well. It is to be noted that the soils at these two places in general show a more acid reaction than those of the lands farther to the eastward on the Pacific side of Guatemala.

At Finca Panamá, Guatalón, both Owen Smith and Merck and Co., Inc. planted many Ledgeriana seedlings. Here as at Zapote the results with the narrow-leaved types have not been satisfactory, while the broad-leaved forms have done well. Only a few trees survived out of some 3,000 "Philippine Ledgers" sent down from Washington, and these were all broad-leaved forms locally considered to be hybrids.

In 1939 Merck and Co., Inc., feeling encouraged by the general progress of the project which had been able to survive in spite of a difficult financial situation among local finqueros incident to the low price of coffee in the 1930's, considered the time had arrived to expand their own activities and purchased Finca El Naranjo, above Chicacao, in the department of Suchitepéquez. The headquarters of Hans Franke and Jorge Benítez were moved to this property (they had previously been living on fincas of the cooperators, Benítez at Zapote and Franke at Helvetia); and F. C. Armstrong, an Englishman with plantation experience in the Far East, was employed as general supervisor of the work. This arrangement was terminated in May, 1940, when Wilson Popenoe was loaned by the United Fruit Co. for six months to assist in developing the project.

Earlier in 1940 B. A. Krukoff, a botanist with extensive tropical experience, had visited Guatemala on behalf of Merck and Co., Inc., and with him had come Frederic Rosengarten, Jr., who remained at Naranjo to assist in carrying out the development of extensive seedbeds at this and other places.

The year 1940 was an important one for the new industry in Guatemala. Not only were large quantities of Calisaya seed from South America planted at Naranjo, at Zapote, at Finca Panamá, at Helvetia and at Patzulín, but efforts were made to organise the experimental work along many important lines. Thus, for example, a uniform system of numbering individual trees for identification was adopted by the collaborating experimenters, after much study and effort on the part of Owen Smith, in particular. The "Individual Tree Record", prepared by Popenoe and Krukoff, was adopted, thus making possible for the first time the preservation of data in an organized form. And bark sampling, now feasible because the Ledgers grown from the Java seed had attained in some instances sufficient size to yield worthwhile specimens, was undertaken on a large scale. Particular credit should be given Mr. Rosengarten for his tireless efforts in securing and preparing bark samples from all areas, samples which were sent to Merck and Co., Inc., at Rahway, New Jersey, for analysis.

In August of this same year William Pennock, who had worked with cin-

chona at the U. S. Department of Agriculture's Experiment Station in Puerto Rico, was employed by Merck and Co., Inc., to undertake horticultural investigations at Naranjo. John Smith, son of Gordon P. Smith, who had returned from the Imperial College of Tropical Agriculture, Trinidad, B. W. I., took charge of cinchona experiments for the interests represented by his father, but left toward the end of the year to volunteer for military service with the Royal Canadian Air Force. His work was ably continued by Percy Davies and Harold Lewonski of Finca Helvetia.

In spite of the progress made during this year—progress along many sound lines—the young industry suffered the hardest blow yet experienced, in the death of Gordon P. Smith of Finca Mocá. Ever since the planting of the Java seeds in 1934, Gordon Smith had led and inspired the local work, and had refused to be discouraged by failures and by the difficulties through which the coffee industry had been passing. For his dogged persistence, his enthusiastic support and his willingness to cooperate at all times and in all ways, the cinchona project in Guatemala owes much to this able agriculturist whose memory will live.

At the end of 1940 Wilson Popenoe turned over the administration of the Merck interests, operated locally as Experimental Plantations, Inc., to Frederic Rosengarten, Jr., who carried forward the activities with vigor and enthusiasm. George W. Perkins, Executive Vice President of Merck and Co., Inc., and his colleague, R. P. Lukens, Director of Manufacturing (who managed the cinchona project from the Rahway end), continued to make occasional visits to Guatemala, as they had done from the start, guiding and encouraging the local cooperators. Both these gentlemen have done much to forward the work, not to mention the heavy investment of funds which they have approved with no certainty regarding the ultimate outcome.

Toward the end of 1940 Hans Franke left Naranjo, and in 1941 William Pennock left. Franke was replaced by Enrique Hoehn, a Swiss citizen with 20 years experience on coffee plantations in Guatemala, and more than usual ability as a horticulturist. Much time was devoted, on all the cooperating properties, to the care and transplanting of the Calisaya seedlings from South America, and to investigation of pressing problems. Of particular importance was grafting. It was during this year that widespread use of this method of propagation came into play, and numerous workers were trained in the necessary techniques. L. Lind Pettersen deserves great credit for taking a leading part in this; Owen Smith at Panamá, aided by Vidal Cabrera, also pushed ahead as did Finca Helvetia, the work being based largely on the pioneering in this field which had been done by Jorge Benítez.

Some of the Problems

Obviously all of this progress was not attained without encountering obstacles, nor without making mistakes. At the start there was the problem of seedbeds. Experience was lacking, and literature on the subject was not too abundant, nor were the practices therein described necessarily the best for Guatemala. The fungous disease known as "damping off" gave trouble the first year or two, but experience showed that it could be controlled through proper adjustment of ventilation and watering.

Attempts to grow cuttings did not turn out satisfactorily, probably due to inexperience—at least with succirubras—since it is now known that this method of propagation is extensively used in several other regions. Budding was tried and not considered very satisfac-

tory until results obtained at Finca El Zapote, mainly with the strong-growing hybrids, were so successful as to encourage others.

With the arrival of Ralph Pinkus at Naranjo in 1942, increased attention was given to problems of propagation at that place. Mr. Pinkus has had excellent success with the side-graft, as opposed to the veneer-graft originally used.

Data from the various centers of experimentation continued to accumulate. There was need of someone to compare growth rates, bark yields, quinine contents and disease resistance of the many clones then growing under different environmental conditions. Dr. John R. Shuman was brought from the United States to do this, and his arrival was timely, as several people who had been involved in the first experiments were gone, records were incomplete in many instances, and the burning question was, Which clones should be planted on a commercial scale?

Growth measurements were taken by thousands, laboratory analyses of bark were brought together for correlation with tree behaviour, and a detailed statistical study (in which Dr. Shuman was aided by Amado Pelén C.) was made of all this information.

It may be said that this work terminated a definite period in the development of cinchona culture in Guatemala; for just at this time the entrance of the United States into World War II threw the cinchona alkaloids into a position of great and immediate strategic importance. Programs aiming to obtain large supplies of cinchona bark in the shortest possible time were placed on foot, not only in Guatemala but also in several South American countries. The history of these projects forms a separate chapter in the romantic tale of cinchona which it is not the purpose of this brief paper to discuss, but which has already been told in part by those who participated.

Editor's Note

Dr. Popenoe's article induced the editor to ask him for some figures concerning the extent of cinchona cultivation at present in the New World. To this inquiry Dr. Popenoe replied under date of June 24, 1948:

"Merck & Co. have 600 acres at Finca El Naranjo [Guatemala]; most of the trees are at least four or five years old. They have another planting near the Mexican border, but I do not know just how large it is. There are good-sized commercial plantings of four or five private growers, and, in addition, the U. S. Government has planted a great many trees on a silvicultural basis at Finca El Porvenir [Guatemala]. I would think it safe to say that there are approximately 1,000 acres in cultivation".

Since these trees have been planted with a spacing of 4×4 or 5×5 feet, there must be about 1¾ million trees under cultivation.

Utilization Abstract

Vegetable Oils of Venezuela. In March, 1949, the Food and Agriculture Organization of the United Nations published a "Report of the FAO Oil-seed Mission for Venezuela" in which the edible oil resources of that country, consisting of twelve species of cultivated and wild palms, and seven species of other crops, are discussed in considerable detail. This report will be either abstracted or reprinted in part in subsequent issues of ECONOMIC BOTANY.

The American Peanut Industry

American production of peanuts was greatly stimulated at the beginning of the present century by the depredations of the weevil in the Cotton Belt. Apart from their use as food, their industrial utilization is only in its infancy and includes conversion of their protein into textile fibers and other products.

C. LEWIS WRENSHALL
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In 1947, for the sixth successive year, the farm production of peanuts in the United States exceeded two billion pounds. Although this production would make a sizeable heap of peanuts, it is not in itself remarkable, being dwarfed by our output of such farm commodities as corn, wheat and soybeans, and being only a small fraction —perhaps as little as one tenth—of the world production of peanuts.

As an article of world commerce, peanuts are valuable principally as a source of vegetable oil. The truly remarkable feature of the American peanut industry is that here peanuts are not produced primarily for oil but rather are classed as a food delicacy. Most of the American crop is eaten in one form or another by the best fed nation in the world.

Peanuts are produced to an important extent in India, China, Senegal, Manchuria, Nigeria, French Sudan, Gambia, Dutch East Indies, Japan, Spain and Argentina, as well as in the United States. In India alone the annual production runs as high as seven billion pounds. China and Manchuria together normally produce about as many peanuts as India. The United States ranks third in order of production. Britain is reported to be planning a considerable expansion of peanut production in Africa.[2]

Historical

It was long believed that the peanut was of African origin, since it spread to other countries from Africa. It is now known to be, like corn, a native of the Americas. Peanuts were grown and used as food by ancient South American Indians who placed funerary jars containing peanuts in the tombs of their dead. Some of these jars, found in a prehistoric cemetery near Lima, were decorated with replicas of peanut pods sculptured in relief, indicating the esteem in which peanuts were held by these people. While the peanut as we know it is not found growing in the wild state, about 15 wild species of *Arachis*, more or less resembling the domestic peanut, have been found in Central and South American countries. An unusual variety, with pods two to three inches long containing two very large seeds, is cultivated by the Nambyquara Indians of Rodanio, Matto Grosso, Brazil.

Probably peanuts were carried from South America to Spain and thence to

[1] Foremost Foundation, a non-profit organization, sponsored by Foremost Dairies, Inc., Jacksonville, Florida, conducts a research program along lines of regional interest.

[2] Concerning this African peanut project, see abstract in ECONOMIC BOTANY 3: 107. 1949.

Africa by the early slave traders. Apparently they flourished in their new home and were relished as food by the natives. From Africa they were carried to the United States and other countries by the slavers who doubtless observed that the slaves arrived in good condition when fed peanuts, which were also a convenient, concentrated form of food for carrying in the holds of ships.

The Spanish peanut, a small-podded variety requiring a relatively short growing season and adaptable to diverse conditions, was introduced from Malaga, Spain, in 1871. Up to this time the peanuts grown in this country were of the larger podded types, derived from African stock. Introduction of the Spanish variety favored the wider spread of peanut culture.

In these early days the growing, harvesting, picking, and processing of peanuts were done almost exclusively by hand labor. Processing did not amount to much, as most peanuts were sold parched or roasted in the shell for out-of-hand eating. Other uses of peanuts were restricted by the large amount of hand work involved in shelling and sorting. Considerable acreage of peanuts were, however, grown for feeding hogs by ''hogging off'', an agreeable arrangement, still widely practiced, whereby the soil is enriched and the hogs do the work of digging and picking, fattening for market in the process. It is said that peanut feeding results in soft pork, while others maintain that it imparts a delectable flavor to the hams.

The rise of the modern American peanut industry dates from the development, in the 1870's, of machinery for picking, cleaning and shelling peanuts. Cleaning plants were established in New York City and Norfolk, Virginia, in 1876. In the succeeding years other plants were erected, and at the turn of the century the Virginia-North Carolina area, then the only important producing district, was well supplied with cleaning and shelling factories.

The spread of peanuts to other areas of the South was greatly influenced by a major disaster which befell southern agriculturalists. This was the incidence of the cotton boll weevil in such serious proportions as to cause many farmers in the Cotton Belt to turn to other crops. First in Texas and later, as the boll weevil swept eastward, in Alabama, Georgia and Florida, the growing of Spanish peanuts in place of cotton became prevalent. In the southeastern section the Runner type of peanut, probably derived from the Wilmington or African variety, became important. Peanut farming was so successful in some sections that farmers came to regard the boll weevil as a blessing in disguise. Indeed, Enterprise, Alabama, which became the center of a thriving peanut-farming area, erected a monument to the boll weevil.

As the growing of peanuts spread, modern cleaning and shelling plants sprang up throughout the South. Beginning in Texas in the early 1900's the industry continued to grow, spreading eastward until peanuts were being shelled in plants throughout the Southeast, and many of the oil mills were crushing peanuts as well as cottonseed. Throughout the First World War there was a veritable boom in peanuts.

In the years following the First World War the prices for peanuts and other farm products declined, and practical measures for controlling the boll weevil came into general use. The acreage planted to peanuts fluctuated considerably, and many areas where peanuts had been grown reverted to other crops. Peanut production settled down to three rather well defined areas, the Virginia-North Carolina area, the southeastern or Georgia-Florida-Alabama area, and the Southwestern or Texas-Oklahoma area.

The long term trend has been toward steadily increased consumption of peanuts. Disregarding annual fluctuations, the per capita consumption has increased from about four pounds in 1919 to almost seven pounds in 1939. Since 1929 the rise in consumption has been relatively steady. With the advent of World War II, consumption jumped sharply, exceeding 11 pounds per capita in 1944 and 1945. It is thus clear that peanuts are to be classed among the staple foods in the American diet.

Food Uses and Food Value

The popularity of peanuts as an American food staple is in many ways a puzzling phenomenon. It would seem that the lowly goober provided at first merely an acceptable substitute for the more expensive and less accessible varieties of nut. In the early days most commercial peanuts were sold roasted in the shell for out of hand eating. In this form they proved popular also with monkeys and elephants. The association of peanuts in the shell with baseball games, carnivals, zoos and circuses continues to this day and in the minds of many people constitutes the chief use for peanuts.

With the advent of a machine-shelled product the tastier salted peanut made its appearance and soon gained wide popularity. Candy manufacturers, too, turned to shelled peanuts for the nut ingredient of their wares. Consumption of peanuts in these forms soon far exceeded that of peanuts in the shell.

It remained for peanut butter, however, to provide the greatest single outlet for peanut as food. After a slow start as a "health food" this simple product—essentially just ground roasted peanuts with salt—has in recent years accounted for about as many peanuts as all other food uses combined.

Although it may be doubted that it has had much to do with stimulating consumption, the fact is that, from the point of view of nutrition, the peanut is almost in a class by itself amongst low priced food products. It is, in the first place, about as concentrated a food as money can buy. One gram supplies 5.8 food calories. This compares with 4 calories per gram for sugar, 3.5 calories for whole wheat, 2.6 calories for bread, 2.3 calories for beefsteak, and so forth. The high calorific value of the peanut is due to its low moisture content—about one percent in roasted forms such as peanut butter—and its high content of oil which makes up approximately 50 percent of the kernel.

The peanut kernel as a whole is highly digestible. The principal constituents are oil, protein and carbohydrate, in that order. The oil is almost completely digestible and ranks with butterfat in food value if vitamin-A content is not taken into consideration. Peanut protein also is highly digestible, either raw or cooked. In fact, there seems to be no reasonable basis for the prejudice against eating raw peanuts. The carbohydrates present are principally ordinary sugar and starch, but the total content is relatively low, making the peanut suitable for use in low-carbohydrate diets.

The peanut's principal claim to nutritional fame lies in its rich content of high quality protein. Vegetable proteins in general are less valuable foods than the animal proteins. The biological value of peanut protein is among the highest of the vegetable proteins and has been reported to be almost equivalent to that of casein. Furthermore, the composition of peanut protein is such as to supplement the deficiencies of the cereal proteins—a good argument for the use of peanut butter. Because it is such an excellent protein source, the peanut compares favorably in food value with more expensive foods of animal origin.

Peanuts are rich in some vitamins, almost wholly lacking in others. In general, the members of the B complex, especially thiamin, riboflavin and nicotinic acid, are present in important amounts. Peanuts are also a good source of vitamin E, but vitamins A, C and D are not present in appreciable amounts. Recent work, as yet unpublished, sponsored by the National Peanut Council at Southern Research Institute, shows peanut foods to be good sources of folic acid, a B vitamin which is now known to play an important role in the prevention and cure of pernicious anemia.

With regard to minerals, phosphorus, calcium and iron are present in significant amounts, while the presence of a number of the so-called "trace elements", such as copper and zinc, has been detected spectroscopically.

From a nutritional point of view there seem to be excellent reasons why peanuts should continue to grow in favor as food.

Peanut Culture

Peanut farming is fraught with problems and difficulties, some of which are the result of the unusual growth habit of the peanut plant, especially the bearing of the fruits underground, while others are related to what might be called the physiological peculiarities of peanuts. In the opinion of many, these drawbacks have been largely responsible for limiting the development of the peanut industry. In fact, considering the potential usefulness of peanuts in both food and industrial fields, it is not too much to say that the future of the industry depends to a great extent upon finding practical solutions to the problems of peanut culture.

Whether or not the peanut should really be called a "nut" at all is perhaps a debatable point. Certainly the name is predicated on the nutty character of the fruit rather than on botanical considerations.

The peanut plant bears many resemblances to other common legumes, such as peas and beans, to which it is, in fact,

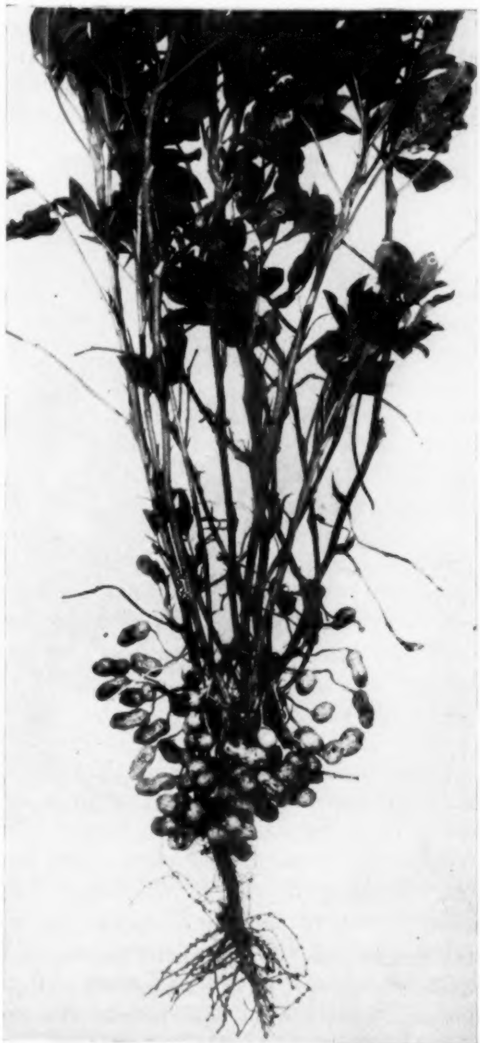

FIG. 1. Spanish peanut plant. Note upright habit, fruits attached to stems but closely grouped around base, separate root system with main tap root and well nodulated branch roots. (*Courtesy Ga. Agr. Exp. Sta.*)

closely related botanically. If only its fruits, like those of its cousins, were found dangling conveniently in the air,

not only would the resemblance be complete but its culture would be greatly simplified. It may even be doubted that the worthy soybean would ever have stood a chance against such a competitor.

It is a common misconception that the peanuts grow on the roots of the plant. This, of course, is entirely erroneous, since the flowers from which the fruits develop are borne in the leaf axils in quite orthodox fashion. Following fertilization the sessile flower, including the peduncle-like tubular calyx, withers and drops off, leaving no trace of its passing visible to the unaided eye. The fertilized ovary lies embedded in the axil awaiting some obscure signal to call forth the next stage of its development. This next stage is the emergence of the "peg", a tendril-like process, bearing the fertilized ovary at its tip. It grows out and down, forcing its way an inch or two into the soil where finally the seed pod and seeds develop.

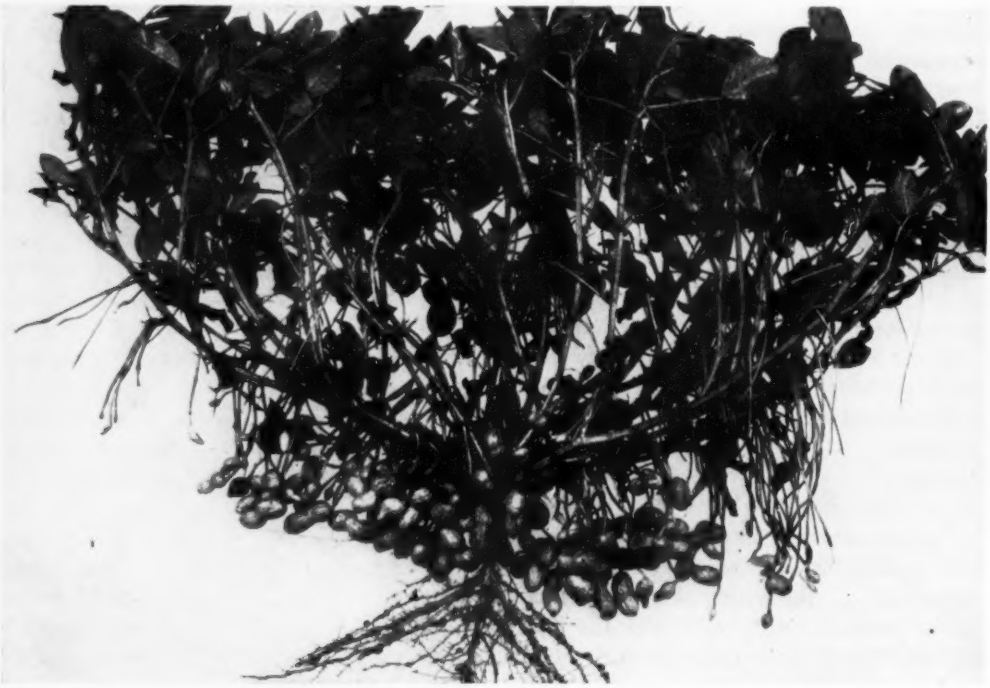

FIG. 2. Runner peanut plant. Note attachment of fruits to prostrate sections of stem branches, also many undeveloped pegs and partly developed fruits. (*Courtesy Ga. Agr. Exp. Sta.*)

Sometimes the peg develops immediately after the flower drops, but it is common for peg emergence to be delayed for days or weeks, and commonest of all for it never to emerge at all. Little is known of the forces and factors governing this phenomenon. It is apparent, at any rate, that only a fraction of the peanut plant's potential productive capacity is realized.

The "pegging down" of the peanut plant, as this stage of development is commonly called, cannot readily take place if the soil is resistant to the entry of the peg. Hence, a prime requirement for growing peanuts is a friable, loose-textured soil. Most peanuts are grown in the sandy soils of the coastal plains

area. Another limitation imposed by this growth habit is that subsequent cultivation must be conducted with due care to avoid disturbing the pegs. This is especially true with the runner type plants which become "pegged down" along a considerable length of the prostrate stem branches.

Nor is the production of peanuts assured by the fact that numerous pegs are sent down into the soil. Development may be arrested at any stage thereafter. Sometimes the pod or shell develops normally but no seeds are produced in it, resulting in what is known as a "pop". The truly strange thing about this is that the developing fruits seem to have their own nutrient requirements, separate from the peanut plant as a whole. Many years ago it was observed that there are root hairs on the peanut hull, indicating that the pods themselves take up nutrients from the soil. Recent work by scientists in both North Carolina and Florida has confirmed that this is so. Apparently proper fruiting depends not so much on the elements available to the plant roots as on the nutrient status of the fruiting zone. Most important is an adequate supply of available calcium in the soil surrounding the developing peanuts. The large podded Virginia types are much more exacting in their calcium requirements. These findings seem to provide ample justification for the practice, long common in Virginia and North Carolina, of dusting the fields with land plaster (gypsum), a source of readily available calcium, about the time pegging down is taking place.

Blossoming of the peanut plant continues over a considerable period, and the same is true to an even greater extent of pegging down. During periods unfavorable to growth, pegging down may be almost completely arrested, to be resumed when favorable conditions again prevail. Thus it cannot be said at any time that a peanut crop is ripe or mature. The farmer aims to harvest the crop when the largest yield of sound nuts will be obtained, but some immature nuts are invariably present, while waiting too long invites deterioration of the fruits that were earliest set.

It is in the harvesting operations that the disadvantages of the peanuts' subterranean development are most apparent. The plants must be ploughed out, or the equivalent, with correspondingly high consumption of mule, horse or tractor power. They must then be shaken free of adhering soil. Since the fresh-dug nuts have a high moisture content, they must be thoroughly dried before they can pass into commercial channels. Curing in the field may take from a few days to several weeks, depending on weather conditions, after which it is still necessary to pick or thresh the nuts from the vines and haul them to market.

Harvesting peanuts in the traditional manner is thus an extremely laborious, long-drawn-out undertaking and one which does not readily lend itself to mechanization by conventional means. Hand labor is still used extensively in shaking, stacking and picking operations. While this may not be a serious impediment to success in countries having abundant cheap labor, under present American conditions it makes peanut production very expensive and prices the product out of the market for many potential uses. An acute need is felt, therefore, for cheaper mechanical methods of peanut harvesting.

While it is obvious that peanut harvesting can never be so simple and direct as the combining of grain crops, recent developments have clearly demonstrated that revolutionary improvements are possible and, indeed, almost within reach at this time. Primary importance can be attached to recent work in Georgia which disproves some of the tradi-

tional ideas concerning peanut harvesting. It has been shown that rapid curing is in no way detrimental to quality and that it is not necessary for the nut to be attached to the plant during the curing process. Also demonstrated was

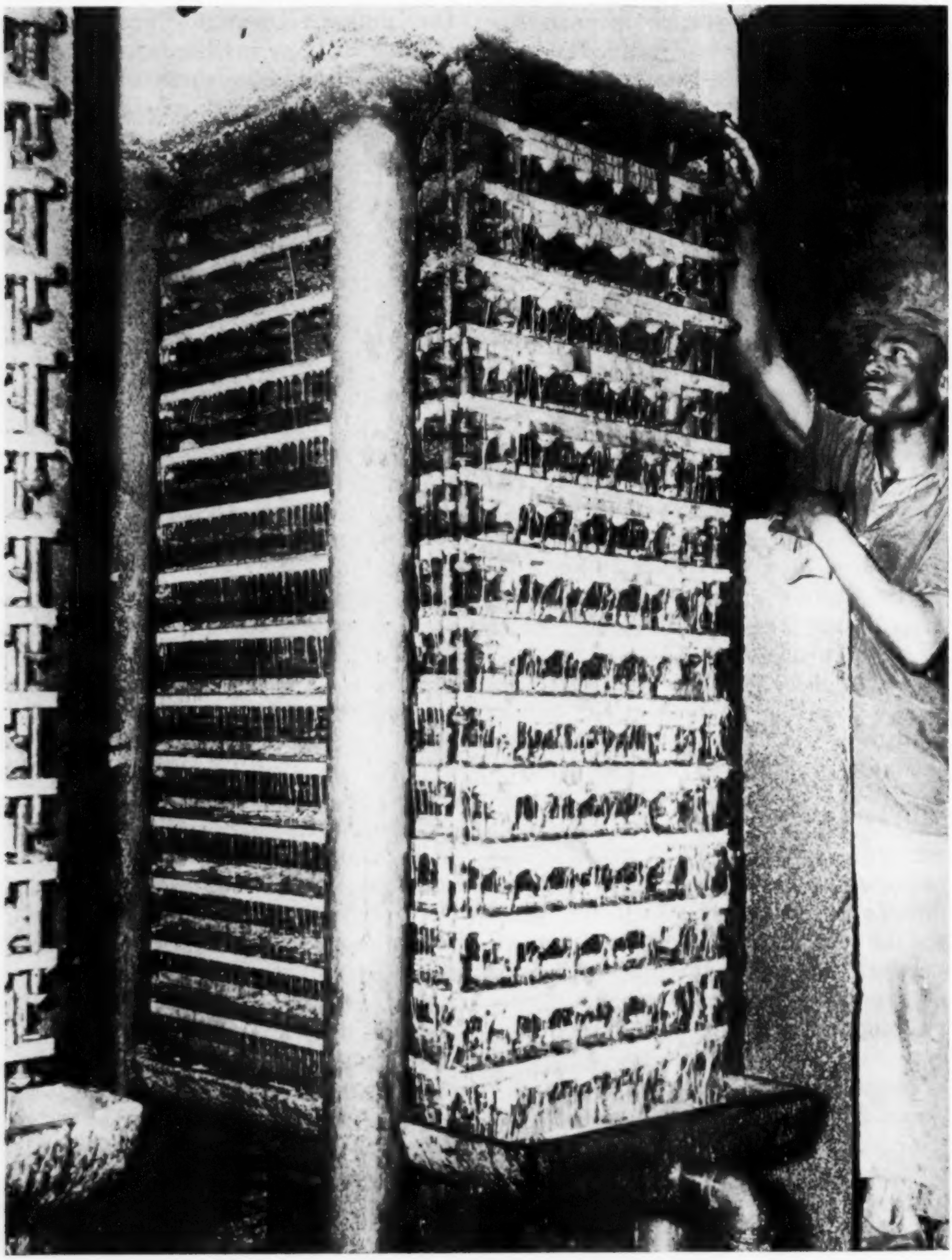

FIG. 3. Peanut oil flowing from plates of a hydraulic press in typical crushing operation. (*Courtesy Stevens Industries, Inc., Dawson, Ga.*)

the feasibility of harvesting the vines separate from the nuts, thus paving the way for the production of high quality peanut hay, practically the equivalent of alfalfa hay.

Other significant advances made in recent years are the development of a two row digger-shaker-windrower by the U. S. Dept. Agri., Soil Tillage Laboratory at Auburn, Alabama, and the experimental use by the Texas Agricultural Experiment Station of a combined harvester for picking up and threshing the nuts after curing in the windrow. Use of the side-delivery rake for windrowing has been practiced in the Southwest for a number of years. Windrow curing has a much better chance of succeeding in the climate of the southwestern producing area. In threshing the crop by the combined harvester the vines are returned to the soil, becoming a favorable factor in conserving fertility.

The ultimate in mechanization would appear to be to dig, shake and pick the nuts in one operation. The vines could either be harvested separately beforehand and handled as a high quality product, or returned to the soil for fertility maintenance at the option of the grower. Such a system would necessitate curing the nuts in the form of green farmer's stock. Now that the fundamental objections to such a practice have been negated by the Georgia results, it remains only to work out practical methods of accomplishing the result. More difficult problems have been solved.

Although it is a legume, the peanut can hardly be regarded as a soil-building crop. Especially when harvested for both hay and nuts it removes large quantities of nutrients from the soil. It has, moreover, unusual ability to feed on the less available nutrients in the soil. Consequently it is soil-depleting and at the same time indifferent to fertilization. After several crops of peanuts have been grown, other crops are likely to show acute symptoms of potash deficiency. Peanuts, however, do not usually respond favorably to potash fertilization. It is abundantly clear that the peanut is highly individualistic in its nutrient requirements. Its peculiarities in this regard doubtless account in some measure for the fact that per acre yields have not changed materially over a period of many years.

The peanut is about normal in its susceptibility to diseases and pests. However, special mention should be made of the so-called "concealed damage" that has been attacking the Southeastern Runners in recent years. Concealed damage is caused by growth of mold, principally between the two halves of the kernel, but to such a slight extent that no deterioration is apparent on superficial examination. The damage shows up when the nuts are roasted, the affected kernels turning dark on application of heat. The presence of appreciable amounts of concealed damage therefore causes down grading of Farmers' Stock.

There is some evidence that concealed damage is caused by a specific organism. The incidence of damage is greatly affected by weather conditions during curing. Rapid curing would probably prove to be an effective control measure. Attempts to develop varieties resistant to this disease are also meeting with considerable success.

Primary Processing

After the peanuts have been grown, harvested and picked or threshed, they are ready to start through trade channels to the ultimate consumer. At this stage they are known as "Farmers' Stock" and are delivered to the primary processors either in bulk or in large burlap bags.

Farmers' Stock is bought according to grade standards published by the U.

S. Dept. of Agriculture. Factors such as moisture content, proportion of dirt and trash present, shelling percentage, concealed damage and size of nuts are taken into account in grading. The grade determines not only the value of the nuts but also whether they can enter edible channels or must be crushed for oil and meal. Sometimes the stock must be dried before it can be stored safely.

Farmers' Stock invariably contains a considerable amount of dirt and trash, such as small stones, stem fragments and mud balls. The first step in processing is to separate as much as possible of this debris from the nuts by means of dirt reels and an array of sieves, blowers and shakers. Despite every effort at this stage some foreign material escapes removal and becomes evident in later processing. The earthy origin of the peanut is probably the cause of more "headaches" than any other single factor in the industry.

When peanuts are to be sold for roasting in the shell the entire process may consist of thorough cleaning and screening for size, and then powdering by rolling with talc in large drums. Usually only jumbo Virginia nuts, grown on light-colored sandy soils to avoid serious discoloration of the shells, are used for this purpose. The powdering process helps to give the shells a uniform light color.

By far the larger proportion of nuts entering the food trade does so as shelled stock. To produce shelled stock ingeni-

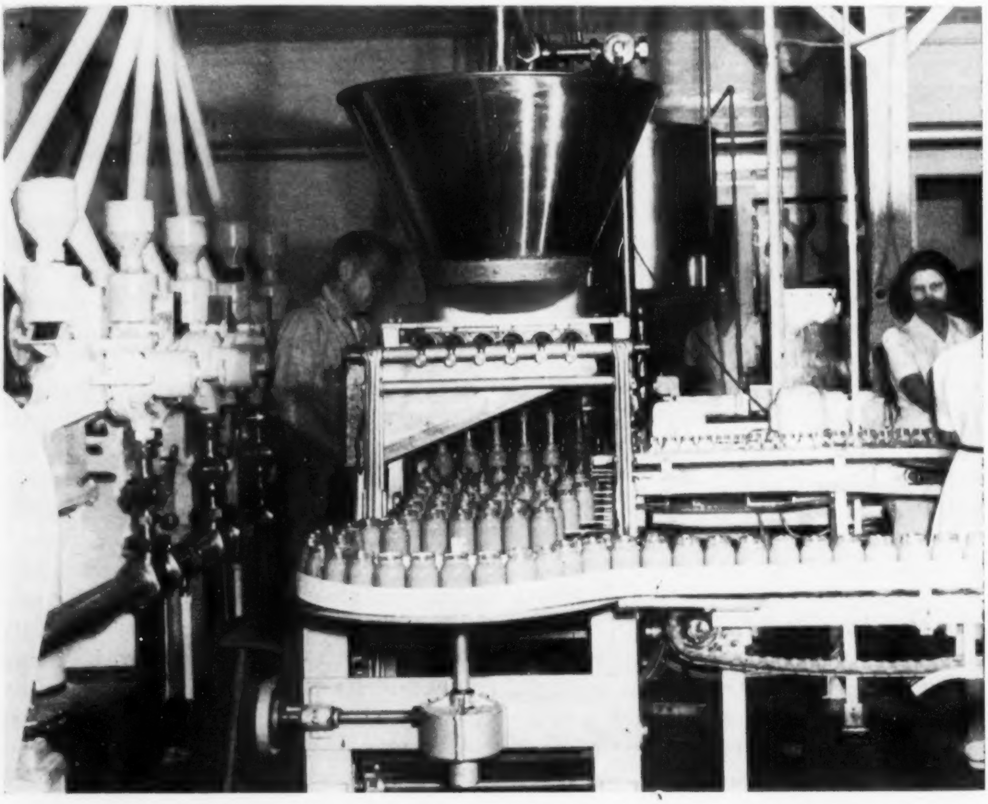

FIG. 4. Automatic filling operation in large scale production of peanut butter. (*Courtesy Cinderella Foods, Dawson, Ga.*)

ous machines break off the hulls so far as possible without removing the red skins or damaging the kernels in any way. The meats are then separated from the broken shells by shaker sieves and blowers. The kernels are sifted to remove splits and shrivels and finally pass over picking tables for the removal of damaged nuts and debris that have escaped mechanical removal. The resulting shelled stock must conform to U. S. grading standards. The splits, shrivels and damaged nuts are relegated to crushing.

When Farmers' Stock does not meet the requirements for food uses, after preliminary cleaning it is shelled and crushed for oil and meal. In this case shelling is not a critical operation, since it makes no difference if the nuts are broken. A proportion of shell material is admitted to the crushing stock to promote oil removal and to standardize the protein content of the resulting press cake meal.

The crushing stock is ground up in a suitable mill and then subjected to a cooking process before the oil is expressed. Most peanut crushing is done with hydraulic plate presses which are also widely used in cottonseed crushing. Recently the more efficient expeller presses are coming into more general use. Solvent extraction has not yet found widespread use in the peanut industry.

Few peanut crushers have facilities for refining the oil they produce. It is usually sold as crude peanut oil to large scale vegetable oil processors to be refined, bleached and deodorized, thereby losing its identity as peanut oil. Relatively little peanut oil reaches the consumer as such. Most of it goes into the manufacture of shortening and oleomargarine where it is used interchangeably with other similarly refined vegetable oils.

The press cake which is the byproduct of peanut crushing is ground to a fine meal and sold as a protein concentrate to manufacturers of mixed feed.

Food Processing

The processing of peanuts for food use involves blanching to remove the skins and some form of roasting or cooking. When whole nuts are required in the end product, as, for example, for whole salted nuts, the process is a delicate one called "whole nut blanching". The peanuts must be lightly roasted to loosen the skins and then run through a machine which gently rubs off the skins without exerting enough pressure to cause the nut to split. When whole kernels are not required the nuts are handled rapidly by a split nut blancher. They pass between belts travelling at different speeds which rub off the skins, at the same time splitting the kernels and freeing the hearts. This type of blancher is used in peanut butter manufacture.

In making salted peanuts it is usual to cook the peanuts in vegetable oil. The batch of nuts is placed in a perforated metal basket, lowered into a vat and literally "boiled in oil" until cooked to the desired degree. The basket is then raised out of the oil and allowed to drain. The nuts are dumped into bins with perforated bottoms and cooled rapidly by drawing air through them. The required amount of salt is then mixed with each batch. Prompt packaging in air-tight containers is of the greatest importance in preserving freshness.

Dry roasting is also a batch operation. Roasters are usually gas-fired. The batch of nuts—from 100 to 500 pounds, depending on the capacity of the roaster—is placed in the rotating cylinder and cooked until the desired color is attained. Whole nut blanching requires a light or "white" roast, whereas for peanut butter a heavy or "brown" roast is customary. Roasters of recent design have

thermostatic control and automatic cut-off when the desired degree of roast has been attained.

Peanut butter is essentially ground roast peanuts with added salt. After roasting to the desired brown color the skins and hearts are removed and the split kernels are ground to the desired degree of fineness by passing through a mill. The required amount of salt is metered in as the nuts are delivered to the grinder. Many manufacturers also introduce one to two percent of hydrogenated vegetable oil at this point to retard separation of oil in the finished product. In some cases other ingredients are added, and additional processing may be given with the object of producing a more or less homogeneous butter.

Peanuts in one form or another enter into the composition of an almost endless variety of confectionery, and it is beyond the scope of this article to discuss the numerous processes involved in the manufacture of these familiar products. However, one operation may be mentioned which is recurrent in every stage of handling peanuts, and that is the use of the picking table to remove defective kernels and extraneous material. Electric sorting machines have found limited application, but most of this work is done by hand.

Industrial Uses

Walter Winchell and numerous other journalists to the contrary notwithstanding, the late Dr. George W. Carver of Tuskegee Institute did not establish a large number of industrial uses for peanuts[1]. As a matter of fact, peanut products do not at present enter into industrial uses to any important extent.

In an earlier publication[2] we reviewed the possibilities for industrial utilization in considerable detail and concluded that some products derived from peanuts have distinct possibilities as industrial raw materials. A very considerable body of technical information on industrial uses has been amassed, largely through the efforts of the Southern Regional Research Laboratory. In a further discussion it was brought out that the high cost of producing peanuts is the most serious obstacle to industrial utilization. Thus the wide scale industrial utilization of peanuts depends to a large extent on agricultural developments leading to cheaper production.

It is thought that products made from peanut protein offer the most promising possibilities for industrial development. The manufacture of textile fiber appears to be of particular interest at the present time, and adhesives, sizes, coatings, *etc.* are recognized possibilities. Plans for commercial scale production of peanut protein textile fibers by an American concern were recently announced. In Britain development of a textile fiber was announced several years ago, and the product was introduced to the trade under the name "Ardil". Since other cheaper proteins are available, it is evident that peanut protein must have pro-

[1] This is a plain statement of fact that is not intended to detract from Dr. Carver's reputation. According to the testimony of his colleagues, Dr. Carver's life was devoted to the task of elevating the standard of living of his people by showing them what could be done with the materials at hand. It seems doubtful that he was even interested in industrial developments. He was as much craftsman as scientist, perhaps more farmer than either. One of his chief concerns was to make his people aware of the value of keeping a cow on the farm. His published contributions on the subject of peanuts were only two:

"How to grow the peanut and 105 ways of preparing it for human consumption". By G. W. Carver. Bulletin 31, Tuskegee Institute. This is a brief treatise on peanut culture, followed by 105 home-kitchen recipes involving the use of peanuts.

"The Peanut". By G. W. Carver and A. W. Curtis, Jr. Bulletin 44, Tuskegee Institute. This is a treatise on peanut culture.

[2] See abstract of this in ECONOMIC BOTANY **1**: 115. 1947.

perties that make it especially desirable for textile fibers.

Outlook

Any attempt to appraise the future of the peanut industry must necessarily be highly speculative. The position of peanuts in America is unique in that our peanut industry is essentially a food industry. In the writer's opinion the food possibilities of peanuts have not yet been fully explored or exploited.

The great nutritional value of peanuts, particularly for the supplementation of cereal foods, makes logical a tremendous expansion of the use of peanut flour or some type of peanut meal. So far the production of edible peanut flour is relatively insignificant. Recently the use of whole peanut meal in making nutritionally superior corn muffins, pancakes, *etc.* has been demonstrated. Commercial production of whole peanut meal is feasible and may provide a new food outlet for peanuts. Another recent experimental development with interesting possibilities is the use of peanuts as the basis for frozen desserts.

It is felt that no large scale industrial utilization can be anticipated until the cost of peanut production can be brought down to such a level as to assure stable supply in a price range that will provide profit to both grower and manufacturer. Industrial uses are not likely to be based on surplus production. However, as has been pointed out repeatedly, the possibilities for industrial utilization do exist if the required balance of economic factors can be attained.

In the face of these long range possibilities, the current crop of peanuts is large and prices are supported at relatively high levels. Thus the industry is confronted with the paradoxical situation of having a surplus while prices are so high as to restrict sales and inhibit the development of new products. Doubtless considerable readjustment of economic factors must be witnessed before a clear picture can be formed of the industry's ultimate potentialities.

Utilization Abstract

Pecan By-products. In the pecan-shelling industry of the South there is a spread of about 3% between the actual meat content of pecans and the amount of salable meat recovered. Since 1943 J. R. Fleming and Co. has been extracting oil from this previously wasted portion and is now processing this fraction from about 90% of all the pecan-shelling plants on the west of the Mississippi River. About 90% of the production is being consumed by the drug and essential oil trade. The Company is also producing about 100,000 pounds of tannin weekly from the shells, some of which is going into the tanning industry, another portion into "drilling mud". Ground pecan shells have been used also in the plastics industry, for "sand-blasting" machinery and airplane engines, and for cleaning raw furs. (J. R. Fleming, *Chemurgic Digest 8(5): 25. 1949*).

Production and Utilization of Alfalfa

Alfalfa, the most important forage crop grown in the United States, is harvested in this country from 15 million acres, and in the 1946–1947 season yielded 34 million tons of hay used principally for feeding stock. About 700,000 tons of alfalfa meal are used in mixed feeds, primarily for poultry, and also serve as a source for extraction of carotene, chlorophyll and xanthophyll.

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History

THE ancient Greeks and Romans were well aware of the value of alfalfa. Cato (B.C. 234–149) in "De Agricultura" wrote of the use of legumes to improve the soil, and Varro (B.C. 116–27) gave some excellent advice on the seeding of alfalfa. The Greek Amphilochus is said to have written an entire book on alfalfa, and agriculturists of that early period were evidently aware of many of the merits of this crop. Columella (A.D. 60) pointed out the superior advantages of alfalfa, such as its long life, the fact that it can be mowed frequently, its beneficial effect on soil, its value as a feed for cattle and horses, and he gave good advice on methods of cultivation.

Hendry (15) has written of the history of alfalfa and has cited sources. According to his account, "Alfalfa probably originated in Mesopotamia and proceeded from there southward into Arabia. The word "alfalfa" is Arabicised Persian, derived from the Iranian word "aspasti", and is traceable to the old Iranian word "aspo-asti" (to eat) and literally means "horse fodder".

According to Pliny, alfalfa was introduced into Greece upon the invasion of that country by the Macedonians and Persians. The plant was named "medic", and this name is retained in the present botanical name, "Medicago". The term "lucerne", often used in Europe, probably is derived from the prominence of its early culture in the Lake Lucerne area of Switzerland, from which it spread throughout northern Europe. Alfalfa was carried to the New World by the Spaniards and became established in the 16th century in Peru and Chile.

George Washington and Thomas Jefferson both grew alfalfa during the Colonial period (2). The two most important introductions from the standpoint of present culture were the introduction in Minnesota in 1857 by Wendell Grimm, of alfalfa brought from the Grand Duchy of Baden, Germany, and the introduction of the Chilean variety in California during the Gold Rush period, 1849–51. W. A. Cameron of Marysville, California, is reported to have produced alfalfa from Chilean seed in 1851. The alfalfa grew so well in the warm and fertile valleys of California that for a time it was known as "California clover".

By constant selection of seed, Grimm was able to develop increased cold resistance in his alfalfa, so that when the

[1] Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture.

importance of varietal differences began to be appreciated, some 50 years later, this northern strain formed one of the parents for present-day commercial varieties.

Taxonomy

The genus *Medicago*, of the large group of Leguminosae, contains about 50 species, of which the purple-flowered alfalfa, *Medicago sativa* L., is most important. Crosses between *Medicago sativa* and *M. falcata*, a Siberian species, are sometimes called variegated alfalfas, and classified as *M. media*. There are several other species which are of importance chiefly because of their possible usefulness for the production of hybrids. One of these, *M. tunetana*, is of Mediterranean origin, and because it propagates readily by means of rhizomes, it may become of importance for pasture forage in the South. There are over 1,000 strains of alfalfa, and the possibilities of plant improvement have just begun to be appreciated.

Breeding

The American Breeders Association (2) reports no deliberate breeding of alfalfa previous to 1903. At the time of that report, 1909, eleven workers were stated as directly interested in alfalfa improvement. Yield, quality and winter resistance were the main objectives of early workers; resistance to disease and plant pests had not become of major significance in the breeding program.

Tysdal and Westover (22) present an excellent review of alfalfa work to 1937. They list the following objectives as being mentioned in reply to a questionnaire sent to all known alfalfa workers (figures in brackets indicate the number of times mentioned in 23 replies): increased seed setting capacity (10); higher yield of quality forage (8); winter hardiness (8); disease resistance (8); suitability for grazing (5); adaptation to different soil conditions (4); resistance to heaving injury (2); resistance to drought (2); insect resistance (2); increased resistance to drought (2); increase in protein content and leaf percentage (2); a type less susceptible to injury from early leaf cutting (1); larger seed (1).

Increase of bacterial wilt disease, stem nematode infestation and leaf-spot diseases has focused attention on the development of improved disease-resistant varieties of alfalfa. Wilt-resistant strains were found in Turkistan, and by crossing with Grimm and Common, wilt resistance was combined with yield and quality characteristics necessary for farm use. Two recently developed varieties are Ranger and Buffalo. Ranger is a cross of Turkistan, Cossack and Ladak, and is recommended for the more northern States where bacterial wilt is serious. Buffalo is an adaptation of Kansas Common, with increased wilt resistance. Other recent introductions include Atlantic, produced for east coast conditions by plant breeders at the New Jersey Agricultural Experiment Station, and Nemastan, a variety found by the Utah and Nevada Agricultural Experiment Stations to resist stem nematode infestation. In the more southern States where wilt is not widespread and cold resistance is less important, Peruvian strains are successful.

Hybrid alfalfas offer promise of even better yields and disease resistance than has hitherto been possible (23, 24). In tests at the Nebraska Agricultural Experiment Station, hybrids yielded 20–27 percent more than Grimm.

Production

Alfalfa is grown in all parts of the United States, but of the 15 million acres in this crop, by far the greatest concentration occurs in the widwestern

and western States. Michigan and California both had over one million acres in production in 1946, and Nebraska, Minnesota, Kansas, Wisconsin, Idaho, Montana and Iowa each harvested over 700,000 acres (26). Approximately one-fifth of the 75,000,000 acres in hay is in alfalfa and in terms of tonnage alfalfa accounts for one-third of the 100-million-ton annual hay crop.

Alfalfa prefers well-drained calcareous loam and does poorly on tight, wet or acid soils. It needs plenty of room for its roots, and a shallow or fluctuating water table at a depth of four feet or less will tend to drown out the stand. On the other hand, in the Platte River Valley in Nebraska alfalfa does very well with a water table of six to twelve feet, and most weeds are rapidly eliminated because of failure of their roots to reach water.

A firm seedbed of good tilth with plenty of soil moisture is required for germination. Shallow seeding is desirable. Caking or baking of surface soil will prevent emergence of the young plants. Young stands that have not established a deep root system are sensitive to drought and to soil temperatures. Planting is customary in the spring and early summer. A nurse crop of wheat or other grain sometimes is sown with the alfalfa. Where high temperatures and drought are apt to occur, as in Kansas, southern California and south-

FIG. 1. Alfalfa, as it appears in a cultivated field. *(Courtesy U. S. Dept. Agr.).*

ern Texas, fall or winter planting is necessary so that a stand is sufficiently established to resist summer conditions.

The amount of seed sown per acre varies in different localities, but under reasonably favorable conditions, 20 pounds is ample to establish a good stand. Some alfalfa producers, especially those who are manufacturing alfalfa meal, favor a heavier seeding of 30 to 50 pounds per acre. They believe that they get more meal from the first two cuttings and that the thicker stand produces thinner-stemmed plants with a higher proportion of leaves. Since 60–80 percent of the protein in the plant is associated with the leaves, leafiness is important. Seeding from airplanes is becoming a standard practice in California.

In areas where alfalfa or legumes have not previously been grown, seed inoculation is desirable to insure nodule formation and nitrogen fixation by the symbiotic bacteria associated with the roots.

Alfalfa meal or hay contains approximately 10 percent ash. Each five tons of annual crop means the removal of 1,000 pounds of soil minerals. The necessity for available minerals is shown in Table 1, which lists the amount and composition of alfalfa ash.

Because of this high ash content and removal of a high proportion of available minerals, adequate potash, lime and phosphate are necessary for maximum yields. Experiments in southern Idaho (21) resulted in almost doubling the yield of alfalfa when yearly applications of treble superphosphate were made during the first three years of a six-year rotation of alfalfa for three years, potatoes for two, and wheat for one year.

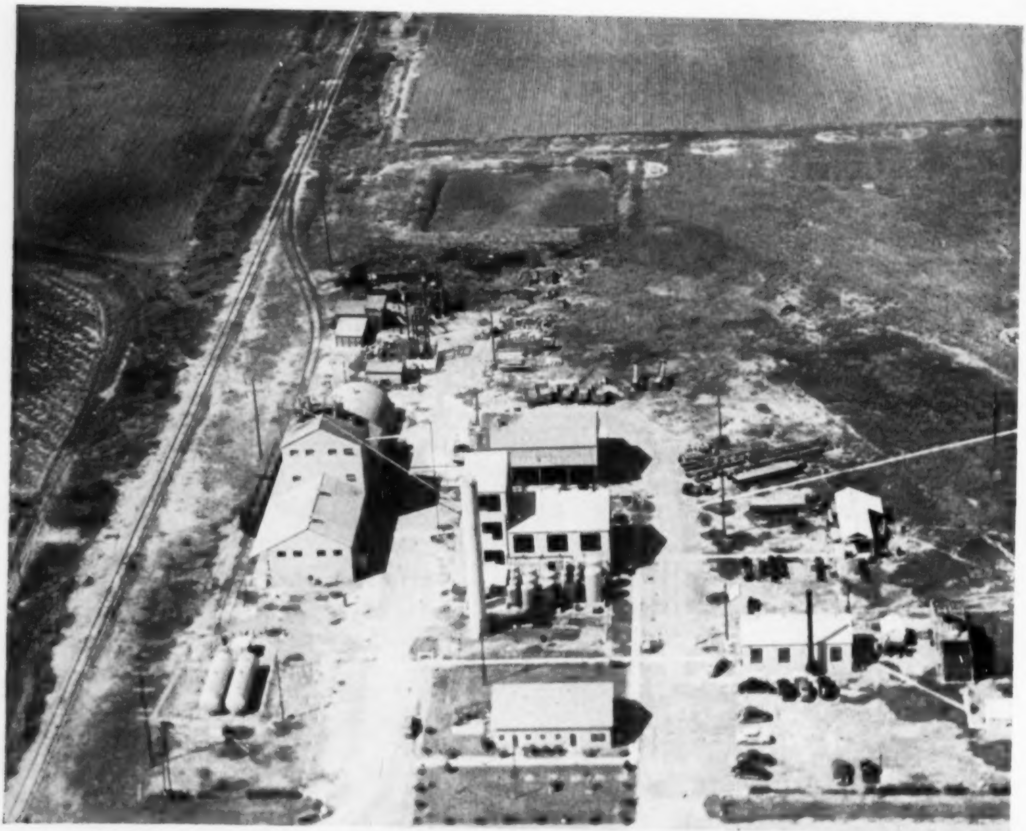
Where the soil is low in available phosphorus, Idaho authorities recommend two or three applications of treble superphosphate at the rate of about 300 pounds an acre. High phosphorus levels in the soil resulted in a higher level of phosphorus in the hay (0.180 percent; control, 0.138 percent) and a yield of 5⅓ tons as against a control yield of three tons per acre. In certain areas 20 or 30 pounds of borax per acre have increased alfalfa yields 50 to 60 per cent (17). Alfalfa pastures usually respond to applications of manure and organic fertilizers.

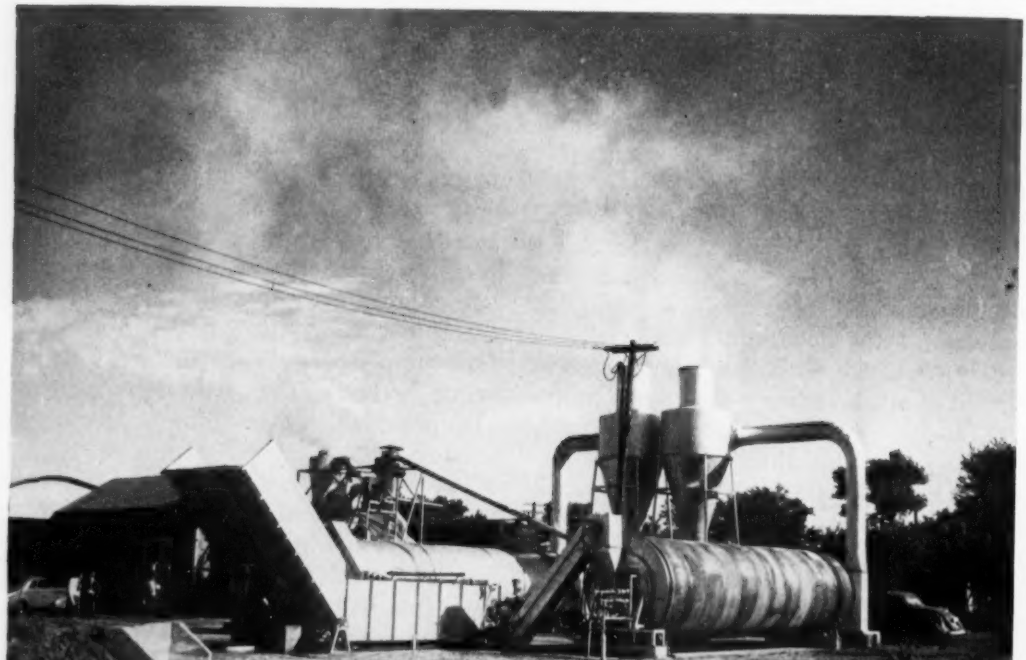
Because it is a nitrogen-fixing legume and also because of the soil depths from which it draws nutrients, alfalfa is not regarded as a soil-depleting crop. This premise is open to question when the crop is grown intensively for cutting and no relief is provided by pasturing, fertilization or crop rotation. Schreiner and Brown (18) list alfalfa as removing 190 pounds of nitrogen for each four-ton-per-acre yield. Fifteen tons of sugar beets together with tops remove 118 pounds, and a 65-bushel-per-acre corn crop takes out 96 pounds per acre. However, these latter crops do not replace any of the nitrogen as does alfalfa. California investigators estimate that a stand of alfalfa will raise the nitrogen level in soils by 60 to 80 pounds per acre per year, and this increased fertility is confirmed by the increased yield of

TABLE 1

ASH IN ALFALFA MEAL (7)

Percentages and pounds per ton			
Leaf meal	11.5%	230	lbs./ton
Standard meal	9.1	180	
Stem meal	7.8	159	
Composition of ash			
Potash (K_2O)	23.5%	54	lbs./ton
Lime (CaO)	40.7	93.6	
Soda (Na_2O)	1.7	3.9	
Magnesia (MgO)	4.9	11.3	
Phosphoric acid (H_3PO_4)	8.5	19.5	
Sulfuric acid (H_2SO_4)	5.7	13.1	
Silica (SiO_2)	9.5	21.8	
Chlorine (Cl_2)	3.0	6.9	





sugar beets or other crops planted in rotation (Table 2).

The time between seeding and harvest depends upon climatic conditions and upon the use for which the crop is intended. If it is intended for hay, the crop may be permitted to reach a one-quarter to one-half bloom stage. Alfalfa intended for dehydration is usually cut in the pre-bloom or one-tenth-bloom stage in order to obtain maximum leafiness. This stage may be reached in 45 to 90 days after spring growth starts. The time varies with weather. Repeated cuttings are made at intervals of 35 to 60 days. If planted by the first of April, cuttings are possible in California according to the following program: May 15, June 25, July 30, August 30, October 5. Under favorable climatic circumstances a sixth or seventh harvest may be had during the late fall and winter months.

As with any crop, many factors affect yield. The average annual yield for California is 4.6 tons of hay or meal per acre. Other States report averages in the range of two to four tons per acre. Under ideal growing conditions much higher yields than these averages can be obtained; seven and eight tons are common, and as much as 12 tons per acre per year has been reported. Once a good stand of alfalfa is established in fertile soil, it will maintain itself for a long period of years, provided diseases such as wilt, leaf spot or stem nematodes are not serious, and provided proper cutting practices are followed. It is desirable that alfalfa enter the winter period with a good supply of nutrients in the crown and roots. Crown buds which develop in the fall are largely responsible for the next season's growth. It is advantageous not to cut too late, but to allow sufficient plant growth in the fall to provide reserves of food material in the plant (12).

Utilization

Alfalfa is the most important forage crop grown in the United States. In 1919 about one-eighth of the total hay acreage was in alfalfa; by 1938 alfalfa was grown on 13.5 million acres, amounting to over one-fifth of the entire hay acreage. The average acreage in alfalfa for the period 1942–46 is reported as 15.3 million acres, with an annual production of 34 million tons. Alfalfa is grown for seed on approximately one million acres. The amount of alfalfa meal produced during the 1946–47 season is reported as 700,000 tons. The economic value of alfalfa varies greatly from season to season and from locality to locality. During the past few years prices have been high, but currently there has been some reduction in price, particularly of the lower grades. Statistics of the U. S. Department of Agriculture (26) list $20.20 as the average price received by farmers for alfalfa

TABLE 2

EFFECT OF CROPPING SYSTEMS ON YIELDS (13)

Cropping system	*Yield in bushels per acre, average 1911–1944*	
	Corn	Wheat
Alfalfa, 4 years; corn, wheat, for 12 yrs.	27.7	19.1
Corn, soybeans, wheat	25.0	16.8
Corn, corn, wheat	20.1	14.4
Continuous cropping	16.1	14.7

FIG. 2 *(Upper).* Cabot's Valley Vitamins, Inc., plant in McAllen, Texas, for dehydrating and chemically processing alfalfa. The solvent extraction building for carotene and chlorophyll production is in the center foreground behind the tank yard. *(Courtesy Godfrey L. Cabot, Inc.).*

FIG. 3 *(Lower).* The Koelling-Thompson alfalfa dehydration plant at Topeka, Kan. *(Courtesy U. S. Dept. Agr.).*

hay, loose, during 1946. Grade No. 1 alfalfa hay, baled, sold in Kansas City for an average of $32.52 per ton.

Many variables affect the quality of alfalfa products. The U. S. Department of Agriculture has established standards for alfalfa hay, and the Association of American Feed Control Officials has defined four types of processed alfalfa. Hay standards are based on leafiness, color and foreign material. Leafiness and absence of coarse stems are of major importance as affecting the protein content of the hay. The amount of green color indicates carotene content and reflects the conditions under which hay was produced.

Standards for dehydrated alfalfa have been defined by the trade rules of the American Dehydrators Association, 53 West Jackson Blvd., Chicago 4, Illinois (3). According to their rules, a product may be called dehydrated "provided that the freshly cut alfalfa having a moisture content of not less than 50% has been artificially dried at a temperature of at least 100° C. or 212° F., that the drying process covers a period of not more than forty minutes, and that there be no admixture of sun-cured alfalfa".

The finer-grade hays find their major use for dairy cattle. Coarser hays are used for horses, sheep and feeder cattle. Hay is often ground to produce alfalfa meal and alfalfa stem meal. A sharp distinction should be made between ground hay and dehydrated alfalfa meals, since the latter are of higher carotene and protein content, and usually command $10 to $20 per ton higher price.

Because the composition of alfalfa hay and meal varies greatly, there exists a wide range in nutritional quality and price. Of primary importance as affecting carotene, protein and fiber content is the stage of growth at which harvesting occurs (Table 3).

Losses of nutritive value during hay production are inevitable. One of the largest losses results from destruction of carotene by sunlight, oxidation and enzyme action during the curing of hay. This loss amounts to 80–90 percent of the total carotene content of the alfalfa plant.

Losses due to inclement weather are of concern in hay production. Even a light rain will leach as much as 20 percent of the nutritives from field hay, and continued rains completely destroy the crop. Fog and heavy dews frequently affect the color of hay and may cause mildew and decay, or if damp hay is stacked, destruction caused by overheating due to microbial activity is likely to occur.

TABLE 3

APPROXIMATE PROTEIN AND FIBER CONTENT OF ALFALFA HAY PRODUCED AT DIFFERENT MATURITIES (15, SUMMARIZED FROM CHART)

	Stage of maturity				
	Buds	*1/10 bloom*	*1/3 to 1/2 bloom*	*Full bloom*	*Seeds ripening*
Proteins	19.5	18.0	17.3	16.0	14.5
Fiber	28.0	30.0	32.8	33.0	35.0

Alfalfa seed production is in some degree a specialized enterprise because many areas do not produce good seed. Several cuttings can be made for hay or dehydrated alfalfa; then the plants can be allowed to mature for harvest of seed. The farm value of the 1.6 million

FIG. 4 *(Upper)*. Loading cut alfalfa into a truck that will haul it to a nearby dehydration plant. This 160-acre field, on the Walter Thompson farm three miles northwest of Topeka, Kansas, was seeded in 1946. In May, 1947, it produced enough to yield about 1½ tons of dehydrated alfalfa per acre. *(Courtesy U. S. Dept. Agr.)*.

FIG. 5 *(Lower)*. An alfalfa cutter, chopper and blower. Dixon, Cal. *(Courtesy U. S. Dept. Agr.)*.

TABLE 4

Approximate Composition of Green Alfalfa, Alfalfa Hay, and Alfalfa Meals (28)

Alfalfa	*Moisture*	*Ash*	*Crude protein*	*Ether extract*	*Crude fiber*	*Nitrogen-free extract*	*Calcium*	*Phosphorus*
	%	%	%	%	%	%	%	%
Immature	79.4	2.9	5.2	0.7	3.8	8.0	0.28	0.09
In bloom	77.2	1.8	3.2	0.6	7.8	9.4	0.39	0.07
Hay	7.2	8.0	15.4	1.6	30.3	37.5	1.51	0.21
Leaf meal	8.5	14.4	20.9	2.6	15.7	37.9	1.42	0.25
Meal	8.2	10.0	15.2	2.2	27.5	36.9	1.56	0.22
Stem meal	9.1	7.7	11.4	1.3	36.1	34.4	....	....

bushels of seed produced in 1946 is quoted as 36.5 million dollars (26).

Dehydrated Alfalfa

The beginning of the alfalfa meal industry occurred in 1903 when Mr. Otto Weiss of Wichita, Kansas, ground alfalfa hay for use in commercial mixed feeds. Later, ground alfalfa was mixed with molasses and used to feed cattle and horses.

As the mixed-feed industry grew, a preference for green alfalfa meal developed. With the newer knowledge gained during the last 20 years about vitamins and related minor components, quality has become increasingly important in the sale of alfalfa products. The first mechanical dehydrators were built about 1930. It has long been recognized that serious losses of valuable nutrients occur during the natural curing of hay. Making hay in many sections is a gamble with the weather, and even when the weather is good, large losses of carotene and other oxidizable nutrients occur, as well as a 10 to 30 percent decrease in protein due to leaf shattering and loss during curing and handling (19). Feeding trials have shown the superior value of dehydrated alfalfa over hay made from the same field (4).

TABLE 5

Production and Prices of Sun-Cured and Dehydrated Alfalfa Meal (18)

Year	*Dehydrated meal, 17% protein*		*Sun-cured meal*	
	Tonnage	*Av. price per ton at Kansas City, Mo.*	*Tonnage*	*Av. price per ton at Kansas City, Mo.*
1943–44	245,000	$55.15	421,000	$39.50
1944–45	377,100	60.30	491,100	43.65
1945–46	497,000	60.40	604,600	44.05
1946–47	566,700	59.30	481,800	43.35
1947–48	707,200	61.65	379,600	43.55

In spite of high cost of equipment necessary for dehydration, the number of dehydrators has increased rapidly, especially in the years following the close of the war. Fortunately, increased recognition of the value of the meal and shortages of other ingredients have maintained price and demand at a high level. Although the production of ground alfalfa hay has remained practically constant, the amount of dehydrated alfalfa has tripled.

Manufacturing Process

Although there are a number of low-temperature tunnel-type driers, most commercial dehydrators use a high-temperature, rotating-drum type which burns either natural gas or fuel oil.

Units are usually located within a five- to ten-mile radius of at least 600 acres of good alfalfa. Operators either raise their own alfalfa or buy from farmers.

In the latter instance the farmer usually produces the alfalfa to a stage suitable for cutting (one-tenth to one-third bloom), and the operator with his harvesting equipment (tractor, mower, chopper, blower, and wagons or trucks) harvests the crop on a price-per-ton-of-meal-produced basis. In California this price is \$8 to \$9 below the current price for baled hay, for example, \$17 to \$18 per ton if baled hay is selling at \$26 or \$27 per ton.

Field chopping of alfalfa in pieces $1\frac{1}{2}$ to 3 inches in length at the time it is mowed makes possible automatic or nearly automatic handling throughout the rest of the process. In the most modern installations the wagons dump their loads on conveyor belts which feed the wet material into the inlet of the drier at a constant regulated rate. The drying capacity of the rotating drum drier is usually about one ton of meal per hour. The chopped alfalfa drops into a blast of hot air and gas, which is maintained at 1,500° to 1,700° F. As the alfalfa travels through the inner drum of the drier, almost instant evaporation of a large portion of the moisture (78–82 percent of the weight of the herbage) occurs with a corresponding drop in temperature of the heating medium to about 250° F. at the exit end. After two more passes through the drier, the chopped dried alfalfa is moved by a large fan through a cyclone

FIG. 6. C. H. Koelling stacks up bags of dehydrated alfalfa at the plant of which he is part owner, the Koelling-Thompson dehydrating plant at Topeka, Kan. *(Courtesy U. S. Dept. Agr.)*.

which drops out large incompletely dried stems and woody fragments. The rest of the material goes through a hammer mill where it is ground to 40- or 60-mesh average size and then to collecting bins for sacking.

In this type of operation, leaves dry in 30–90 seconds and are blown through the machine with that rapidity, while stems and heavy pieces require four to six minutes. A system of controls is used which automatically cuts down on the fuel if too little alfalfa is fed into the machine or if for some other reason the exhaust temperature rises. The amount of heat required to evaporate the moisture from the alfalfa as it is fed to the machine requires accurate control. During continuous operation the amount of fuel remains constant and the rate of feed of green alfalfa is varied to balance the heat input.

One and sometimes two men are required to feed the green alfalfa into the dryer, watch the gauges and guard against stoppages. Another man handles bagging of the meal. Where alfalfa leaf meal is produced, the meal as it comes from the hammer mill goes through automatic sifters. Because leaves produce a finer powder than the more fibrous stems, leaf meal goes through the screens and is sacked separately. The coarser particles remain on the screens and are sold as stem meal. The proportion of leaf meal to stem meal depends upon stage of maturity at harvest and type of grind and setting of the mill and screens.

Frequent chemical analyses are needed to insure control of protein and fiber content in the finished meals. The installation and operation of a complete alfalfa meal and dehydration plant is a business of considerable magnitude, requiring between $100,000 and $200,000 in capital and demanding a combination of business, mechanical and farming skills. The overall cost of production after the alfalfa is purchased from a farmer may vary from $15 to $23 per ton, depending upon length of season, investment, labor and operating costs, and especially fuel prices. During periods of low prices, freight rates to centers of distribution may be an important factor in the success or failure of operation.

The price of alfalfa meal is largely determined by the percentage of protein, although to an increasing extent the feed trade is demanding a guaranteed carotene content for the better meals. According to the grade of alfalfa, labels on each sack commonly guarantee the minimum percentage of protein and maximum percentage of fiber, and perhaps ash and fat content.

Uses in Animal Feeding

Although only about three percent of the total tonnage of alfalfa is now converted into meal, it is the writer's opinion that this proportion will continue to increase as a result of advancing nutritional knowledge relative to the proper use of alfalfa in mixed feeds and also as a result of technical improvements which will serve to increase and stabilize nutrients such as carotene (provitamin A), riboflavin, thiamin, pantothenic acid and choline. Alfalfa meal supplies about one and a half times as much protein as most grains and about half the nitrogen-free extract (carbohydrate) which grains contain. The protein provides such essential amino acids as arginine, threonine, lysine and tryptophan but is somewhat low in cystine and methionine. Dehydrated meal is particularly rich in dietary factors supplied by green forage or good green pasture and is therefore widely used to supplement poor hay and increase feed utilization during the winter or when green feeds are not available.

Three to five percent of good dehydrated alfalfa is recommended in poul-

try feeds. This amount will supply nearly all of the vitamins A and E needed and about half the requirement of riboflavin as well as considerable quantities of choline, thiamin, folic acid and "grass juice factors". Numerous investigators have reported improved hatchability, lowered mortality, rapid growth, better feed conversion and increased egg production occasioned by the use of mixed feeds containing adequate but not excessive amounts of alfalfa. For turkeys a somewhat higher level of meal, 5–10 percent, is advocated. For further discussion of the use of alfalfa for poultry the reader should consult Handbook of Poultry Nutrition by W. Ray Ewing (10).

TABLE 6

COMPOSITION AND APPROXIMATE CONTENT OF MINOR CONSTITUENTS OF FRESH ALFALFA MEALS (19)

	Leaf meal	*Standard meal*
Crude protein	22.7%	15.7%
Nitrogen-free extract	39.2	37.9
Crude fiber	16.3	26.8
Crude fat	2.8	2.0
Ash	11.5	9.2
Moisture	7.4	8.4

Minor constituents (leaf meal)	*ppm.*
Chlorophyll	3000
Xanthophyll	425
Carotene	300
Phytol	1000
Vitamin E	250
Vitamin C	4000–9000*
Riboflavin	120
Folic acid	12
Choline	900
Panthothenic acid	40
Vitamin K	80–100
Niacin	50
Thiamin	7

* Vitamin C is retained only under special condition of dehydration and storage.

In swine feeding, dehydrated alfalfa meal has shown particular value in increasing breeding efficiency, improving lactation, and increasing the average number of pigs weaned per litter. The use of 10 to 15 percent or more in the ration is recommended by Professor Damon Catron of Iowa State College (8).

Chopped (not ground) dehydrated alfalfa as well as sun-cured hay finds its most extensive use in cattle feeding. The manufacture of pellets of meal with about 10 to 15 percent of molasses added increases palatability by eliminating the qualities of a light meal that are objectionable to cattle.

In spite of its advantages, alfalfa is by no means perfect. Disadvantages when fed in excessive amounts to poultry include lack of palatability, high fiber content and a tendency to decrease rate of growth of chicks and broilers. Whether these difficulties can be overcome by the wet-processing method of making a high-protein concentrate, with elimination of fiber components, is not yet known.

Other Uses

The writer believes that the industrial utilization of alfalfa is today in an infant stage which compares with the development of the corn and soybean industries 30 years ago. Alfalfa is more difficult to process than the grains, but the advantages of an industry based on a plant which takes nitrogen from the air and produces more protein per acre than almost any other crop are obvious.

Vitamin C and other water-soluble vitamins could be recovered from alfalfa juice. Several companies are using or have used alfalfa meal as a source of carotene (provitamin A), chlorophyll and xanthophyll. The process in barest detail involves the solvent extraction of high-quality leaf meal with hexane or other solvent, concentration of the solvent, and separation of the chlorophyll and carotene by chemical processes. The carotene concentrate has found use as a replacement for vitamin A in feeds. Chlorophyll is used in pharmaceutical and air-purification products (14). With adequate research, no doubt economical methods of obtaining phytol,

choline, vitamin K and other compounds listed in Table 6 could be developed.

The use of alfalfa in human nutrition has been suggested and tried, perhaps first by Nebuchadnezzar when he got down on his knees and ate "grass", for his was the area in which alfalfa may have originated as a forage plant. More recently Brown and Tisdall (6) reported the use of two percent of alfalfa meal in special cereal mixtures for undernourished children because of its high vitamin A content. Fox and Wilson (11) have published a bulletin, "Lucerne as a Food for Human Consumption", in which they point out that the leaves of alfalfa contain five times as much vitamin C as oranges, grapefruit or any of the common leafy vegetables. They also discuss the value of the protein, minerals and vitamin A of this plant for human food. They suggest using alfalfa leaves in green salad and omelettes, in cooked form like spinach, or in tea. They report the use of alfalfa as a vegetable in China and parts of central Russia. In this country dried alfalfa leaves mixed with mint are packaged and sold in most health food stores. It is possible that a variety of alfalfa could be developed which would be sufficiently tender and bland in taste to win acceptance as a vegetable.

The "wet processing" methods of fractionating green alfalfa offer promise for new alfalfa products. Nebraska Chemurgy Project Bulletin No.6 (25) reports experiments on grinding green alfalfa through an expeller press which separates the juice containing the plant pigments and most of the protein from the fibrous material. The dried juice contained 40 percent of protein and retained about 90 percent of the carotene found in the plant. Bickoff, Bevenue and Williams (5) have reported a similar process, using a Rietz disintegrator and pressing to recover a pigment-rich juice. A firm in Los Angeles manufactures an alfalfa powder made by spray-drying alfalfa juice pressed from green alfalfa. Chibnall (9) has reported on methods of concentrating the chloroplast pigments contained in the plant juice by centrifuging. They can also be concentrated by heating the juice until coagulation of the protein occurs, as described in the Nebraska report (25) and by Bickoff *et al.* (5). Paper has been manufactured from alfalfa fiber.

Research Problems Related to Industrial Utilization

There are many problems to be solved in handling alfalfa. Some of them concern the feed trade and the consumer to an extent little realized by those outside the feed industry. Both carotene from alfalfa and vitamin A from marine sources are destroyed in feeds by a few months' storage at summer temperatures. Clarence Johnson of Ralston-Purina Company (1) has estimated that the economic value of carotene lost between the time alfalfa is cut and when it is fed amounts to 13.5 million dollars annually.

Stabilization by means of packaging in inert gas has been investigated (16, 29). Other investigators (20) have shown that low temperatures (32° F.) and vacuum packaging were both very effective in reducing carotene losses. Aside from cold storage, industrial methods for preventing losses have not been developed. It has been suggested that packaging in modern multiwall paper bags with nitrogen or carbon dioxide would prevent some of this loss.

Industrial processes for eliminating fiber content and increasing palatability still await development. The chemical fractionation of alfalfa is an infant industry deserving of attention. Much clinical work could be done on alfalfa components such as chlorophyll and water-soluble vitamins. Almost unlimited nutritional work can be undertaken to supplement the little now known

about feeding alfalfa and to determine the value of various alfalfa fractions.

It is encouraging to note that the American Dehydrators Association has formed an Alfalfa Research Council and expects to encourage and finance research on problems related to the industry.

The Western Regional Research Laboratory of the U. S. Department of Agriculture is working on the physical and chemical fractionation of alfalfa and the characterization of the various fractions. A number of State Experiment Stations, particularly in States having large dairy industries, and private firms and individuals are also engaged in research on alfalfa. With this impetus many interesting developments and continued growth of present enterprises can be expected during the coming years.

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Microbial Farming

Does the production of proteinaceous food by extensive cultivation of baker's yeast in England and Germany during the recent war presage an eventual source of supplementary food for the world through the utilization of microorganisms?

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Introduction

RAPID advances in the science of nutrition during recent years have led to a critical reexamination of our present system of agriculture. Farm products are no longer estimated solely in bushels or tons per acre but are evaluated in terms of the quantities and qualities of the essential nutrients they contain. Today agriculture is thus planned according to man's dietary needs.

Basically agriculture is a process of transforming the materials of the soil and air into various forms of food and other products with sunlight as the primary source of energy. How efficient the agricultural practices are depends, therefore, on how much energy they can fix or transform, and on how much inorganic material they can render into forms available for human use. From this point of view a critical review of our present agricultural situation can be made, and, what is more important, a number of interesting prospects can be discerned on the broadened horizon. Among these prospects the possibility of using microorganisms as major crops appears to be most interesting and fundamental.

Although the use of microorganisms in the production of food is an art as old as history itself, until very recently it played only a secondary or minor role. Microbes were primarily used, unwittingly at first, to improve the taste and the digestibility of the food, as in the cheeses of Europe, soybean products of Asia, 'poi' of the Pacific islands, and the native beer of Africa. Later they were used to supply certain essential nutritive factors, for example, vitamin B in the form of yeast tablets and yeast extracts. Only during the two world wars, however, was serious attention given to the possibility of using microorganisms to furnish the more bulky, body-building and energy-producing articles of food, such as proteins and fats. Experiments have shown that in many cases these food materials can be produced satisfactorily in respect to both quantity and quality, by means of microorganisms. Furthermore these organisms can do the job more efficiently and quickly than the higher plants and animals that we now employ. The culture of them requires comparatively less labor and very much less space. They can be grown in factories instead of fields. Consequently they are less dependent upon the natural and climatic conditions and are more compliant to human control. Considering these obvious advantages, it is reasonable to imagine that some day in the future "microbial farming" will form an integral part of, if not wholly replace, our present system of agriculture. In view of the bitter experiences during two world wars and the famine situation of the post-war period, a quick and efficient way of mass production of food in a con-

centrated form will certainly engage serious attention. Industrial concerns, ever eager to expand their activities, will find in it a long-sought opportunity to enter the field of farming because it promises an immediate turnover and is well adaptable to their technical facilities.

Of course, agriculture supplies us not only food but also other materials. Fibers, resins, latex, dyes and drugs are the notable examples. But all these non-food products are rapidly being replaced by the synthetic substances of modern chemistry. Perhaps food products, too, will some day be synthesized; indeed, some have already been patented. However, as far as we can see, the day is still far off. And before that time we shall have to be content with the living organisms for our food supply. Among the living organisms, as we have shown, the microorganisms appear to answer our requirements and to fit into our industries best of all.

The principal classes of food are the proteins, fats, carbohydrates, vitamins and minerals. All these substances are known to exist in some forms of microorganisms. A complete diet, satisfactory at least theoretically, can be obtained exclusively from a mixture of these organisms. Of course, many problems will have to be solved before such a major change can be realized. The choice of organisms, the process of production, the nutritive values and the palatability of the products remain to be investigated in greater detail. Parts of these questions have already been answered, as shown in the following examples. In the rest, it will be seen that a microbial crop is already established in commercial production; in the second, that one is still in the laboratory stage; and in the third, that the organism is still to be selected and domesticated, for thus far it has not been considered as a potential source of food.

Proteins

Let us begin our discussion with the microbial production of proteins, the most important and often a limiting factor in our food supplies. As early as the first world war the Germans were known to have developed a strain of yeast for the production of protein. The yeast was produced on a commercial scale to supplement the deficient diet during the blockade. The first experiment was not very successful, owing perhaps to improper administering of diet composition. In the second world war considerable progress was made, and thousands of tons of protein yeast were produced and used with satisfactory results. In the allied countries similar investigations were carried out, and commercial processing technics were developed. Since the food situation was then less urgent the experiment did not get much beyond the pilot plant stage and no large scale production measures were attempted until near the end of the war.

The organism developed in the British laboratories is a strain of baker's yeast, *Torulopsis utilis*. When dried in the form of flakes it is cream white in color, has a meat-like taste and is very rich in protein and the B-vitamins. As shown on the following page, weight for weight it contains about twice as much protein as fresh beef or dried whole milk and about the same as soybean. It has all the essential amino acids in good balance, and is especially rich in lysine which is usually deficient in the proteins of plant origin. Food yeast lacks vitamin A but is very high in the B complex; in fact, yeasts in general have long been used as a source of these vitamins. Feeding experiments have shown that pigs thrive well on a diet entirely of maize supplemented with 5% to 20% of food yeast. Nutritive trials on school children have indicated that inclusion of yeast in their biscuits and milk leads to a greater increase in body weight.

Torulopsis yeast grows very rapidly. It has a generation time of two to four hours, or a tenfold increase in ten hours. It can be cultured in a continuous manner, and once inoculated the cultures can be kept going with periodical additions of nutrients and withdrawing of the suspension of yeast cells. Sugar or molasses can be used as the carbohydrate source, and nitrogen and phosphorus are supplied as ammonium sulphate and superphosphate. The conversion of inorganic nitrogen to protein is almost quantitative, or 100% theoretical. More than half of the carbohydrate supplied is converted into protein, and most of the remainder into the other cell substances. The maximum overall efficiency as a converter of food energy is many times that of vertebrates. Thus, whereas the pig, the most efficient food producer among farm animals, retains 20% to 40% of the calories taken in as feed in the increase of body weight (0.036–0.073 gram of solid per calorie), and only a part of it is edible, yeast shows an efficiency of 50% or even 60% and yields 0.125–0.25 gram of solid corresponding to 0.6–1.1 calories per calorie intake. The efficiency of the production of vitamin B is even more striking, being 10 to 200 times that of any animal product per calorie of feed.

A commercial factory for producing food yeast has been projected by the British Colonial Office in Jamaica in cooperation with the West Indies Sugar Co., Ltd. The factory proper will have a ground space of about 20,000 square feet and cost £110,000 to build. The total personnel and labor will be about one hundred, and with a little addition will be able to handle expansion of the factory to twice its present size. The factory will produce 12 tons of dried yeast in 24 hours. Using molasses as raw material the cost of producing dried food yeast will be about sixpence (ten cents) per pound.

Similar commercial plants for food yeast have existed for sometime in Germany, and others have been recently established in America, Sweden and elsewhere. Such factories constitute an ideal means of improving the dietary of people depending chiefly on cereals, and are especially suitable for countries having a low standard of living.

Yeast is by far the cheapest method of producing protein from carbohydrates and nitrogen. To produce the same amount of protein as a yeast factory of the above mentioned size would require a hundred thousand head of cattle. Besides, far more space and labor would be needed. Animals can synthesize proteins only indirectly. Inorganic nitrogen supplied to the soil has to be first

Composition of Food Yeast, *Torulopsis utilis*, compared with that of some other foods

	Water %	Protein %	Fat %	Available % Carbohydrate	Calories per 100 gr.	Calcium mg. per 100 gr.	Fe	Vitamin A	Vitamin B	Riboflavin	Nicotinic acid
							mg/100g	IU/100g	mg/100g	mg/100g	mg/100g
Food yeast	8.	43.1	2.4	3.0	206	127	20.0	0	2.0	5.0	40–45
Dried milk	4.	25.6	26.7	35.6	485	895	0.8	1.070	0.3	1.15	24
Beef	69	19.0	10.0	0	166	10	4.0	50	0.08	0.25	43
Dried peas	7.	24.5	0	50.0	298	61	4.7	200	0.45	0.30	18
Soybean	8.	40.0	18.0	12.6		210	7.4	16–350			

From "Food Yeast, a Venture in Practical Nutrition," 1941, and "Soybean" Cornell 1945.

transformed by plants in order to be of use to them. Both transformations are quite inefficient, and the process entails a double loss of material. Even land supporting leguminous plants, which yield proteins directly available as human food, is much less efficient acre for acre than land made to yield sugar for the growing of yeast. Furthermore, as substitute for sugar, nearly any carbohydrate properly treated can be used by yeast. Hydrolyzed sawdust, pulping waste and many kinds of inedible carbohydrates have been tried with success. Since all plants produce carbohydrate in one form or another, the variety of raw material is practically unlimited. Yeast requires no products of organic origin besides carbohydrate. Phosphate is obtained in the earth's deposits, and an inexhaustible nitrogen supply can be derived by artificial fixation from the atmosphere.

Fat

Another important constituent of food is fat which supplies energy in a concentrated form and often contains vitamins A and D as well as other growth factors. One gram of fat gives upon oxidation in the body, nine calories of energy, *i.e.*, about twice as much as that given by the same amount of carbohydrate or of protein (4 cal./gm.). It is digested more slowly, stays longer in the body, and for these reasons is generally used in cold climates and in emergency field rations where bulk and weight are important considerations.

The fact that microorganisms can synthesize fat like the higher plants and animals had been long known but had not been industrially investigated until the first world war. Because of the shortage of fat the Germans were compelled to produce yeast fat on an industrial scale. The organism used by them was *Endomyces vernalis* which under favorable conditions can produce fat equivalent to 20% to 25% of its dry body weight. A great deal of research was done on the problem in the Institüt für Gärungsgewerbe in Berlin. The optimal conditions for growth appear to be 15° to 20° C temperature, good aeration and a medium rich in sugar and nitrogen. But to obtain high content of fat the nitrogen supply must be reduced to a minimum. Fat accumulation is also favored by the presence of alcoholic vapor in the air. The production of fat by the organism apparently consists of two phases. First the organism is allowed to multiply rapidly to give large quantities of cells; then the cells are "fattened" in a medium of low nitrogen. Several industrial processes have been developed on this basis. For good aeration the organism is generally grown on surface cultures. The yield obtained is usually about 10 grams of fat per 100 grams of sugar consumed, although in some cases 30% conversion has been reported. Instead of sugar, molasses, sawdust, hydrolyzed wood and other cellulosic wastes can be used. The fat so obtained is recovered either by extraction or by autolysis. It keeps well in the absence of air.

Yeast fat contains palmitic, oleic, linoleic, lauric and other fatty acids as well as phospholipids, lecithins and sterols. No feeding experiments have been published using the yeast product as a sole source of fat, but judging from its composition, yeast fat probably does not differ much nutritionally from other fats of plants and animals.

There are many other fungi which accumulate fat in their mycelia, for instance, *Penicillium*, *Aspergillus*, *Fusarium* and *Oospora*. Among these, *Penicillium javanicum* van Beyma can yield as much as 40% fat of its dry weight. Semi-large scale apparatus for its production has been worked out and tried

with success. Recently a new strain of yeast, *Rhodotorula gracilis,* has been developed by scientists in Sweden. Its fat yield is even higher, over 60%. The analysis of this yeast and that of the protein yeast are as follows:

COMPARISON OF PROTEIN YEAST (*Torulopsis utilis*) AND FAT YEAST (*Rhodotorula gracilis*)

(From Enebo, Anderson and Lindin, 1946)

	T. utilis %	*Rh. gracilis* %
Protein	59	13
Fat	3	60
Carbohydrate	30	24
Mineral substances	8	3

The essential conditions for fat accumulation are, again, a low nitrogen and phosphate supply. There is a reciprocal relation between fat content and protein content. With plentiful nitrogen and phosphate salts the organism grows rapidly (one generation in about three hours) and accumulates a large amount of protein but has very little fat. When the mineral supply is decreased, the growth rate decreases to one generation in eight to nine hours with an increase in fat content to 20%. When the mineral supply is at the lowest, growth is slowed down to one generation in 15 to 20 hours, while the fat content runs up to 60% of its dry weight.

Because of the slowness of the process of fat formation, continuous production, as with protein yeast, is not industrially feasible. Two methods of commercial production are suggested. One is to grow the yeast continuously with plentiful minerals to obtain a rich big harvest of cells with comparatively low individual fat content. These cells can be used for both their fat (15% to 30%) and protein (15% to 35%). The alternative method is to culture the yeast in batches in a low mineral medium to obtain a high percentage of fat in the comparatively smaller number of cells. A process combining the merits of both has been tried out satisfactorily in Sweden. The yeast is first cultured continuously in a mineral-rich medium, and portions are taken out periodically to be fattened in batches. Industrial production of fat yeast from hydrolyzed wood was known to have been planned in Germany in 1944. Details of the species and conditions of culture are not available. Judging from the war situation at and immediately after that time, full scale operation was probably never realized.

The efficiency of fat production by *Rh. gracilis* has not been surpassed either in microorganisms or in higher forms. For 100 grams of sugar intake a yield of nearly 18 grams of fat can be expected. And the rest can largely be accounted for in the proteins and carbohydrates of the cells. Assuming that two grams of sugar are needed to produce every gram of cell protein and carbohydrate, it is estimated that about 4.5 grams of sugar are used to form one gram of fat, or an energy efficiency of about 50%. It is difficult to compare this figure with that of higher plants or animals. As shown in the above section, their energy efficiencies in general are always low. Common experience also indicates that the fattening of animals is a very wasteful process. Whatever the case, we must remember another important point, that no animal or higher plant can accumulate as much fat as would amount to 60% of the total dry weight of the body as a whole.

In spite of its efficiency as a fat producer, yeast has so far not been produced commercially with profit except under particular conditions, as in the war. But with improvement in strain and technique there is no good reason to exclude microorganism from competing with higher plants and animals as fat sources, even in times of peace.

It may be added here that all yeasts are rich in ergosterol which upon irradiation acts as vitamin D. In fact, commercial vitamin D is derived mostly from this source. The colored species of yeast contain also pigments of carotene, which are closely related to vitamin A. Recently it has been reported that *Rhodotorula gracilis* shows a vitamin A activity of five to ten International units per gram of dry weight, a figure comparable with that of dried whole milk. Lastly it must be remarked that yeast fat contains linoleic acid which has been shown to be necessary for growth but is not synthesized by animals.

Carbohydrates

It remains for us now to consider the last major class of food, carbohydrates. This group supplies both the energy for growth and the raw material for syntheses of all the other forms of food. In the above examples, be it the production of protein or of fat, the basic material is always a carbohydrate. It is true that our world is fairly well stocked with carbohydrates of the higher plants, and there is no immediate danger of shortage. Nevertheless there are places where the supply of this important material is too limited. As it is, agriculture still cannot operate in many parts of the earth and is not always dependable at all times. The space required by farming and the bulk of its products further restrict the transportability and availability of agricultural produce. A consideration of the production of carbohydrates by microorganisms is, therefore, of more than theoretical interest.

Of course, all microorganisms produce carbohydrate, but most of them are essentially converters rather than primary synthesizers; they transform one carbohydrate into another. Here we shall consider only the autotrophic forms which make carbohydrates from carbon dioxide and water. The energy for this synthesis may come from sunlight or from oxidation of inorganic substances. All algae and some bacteria belong to this category. So far none of these organisms has been investigated or cultivated with a view to developing them into a carbohydrate crop.

The one organism that has been subjected to somewhat extensive cultivation is *Chlorella vulgaris*. It is a unicellular green alga widely used by physiologists in researches on metabolism. Its composition is approximately as follows:

The carbohydrate fraction consists of polysaccharides hydrolyzable by 3% acid. It includes approximately 70% of "hemicelluloses," 28%–30% starch, 4%–5% disaccharides and 4%–6% hexoses.

The organism requires no organic material for growth. Being photosynthetic it manufactures its own food out of carbon dioxide with the energy of light. It is usually cultured in a dilute solution of inorganic salts such as $MgSO_4$.KNO_3, KH_2PO_4 and a trace of ion. The cultures are illuminated either with indirect sunlight or with incandescent lamps. A stream of air containing 5% carbon dioxide is bubbled through the medium to supply raw material and agitation.

In such cultures the organism grows first rapidly and then more slowly until a saturation point is reached. During the period of exponential growth the population can under suitable conditions increase two hundred fold in four days, corresponding roughly to a generation time of 11 to 13 hours. This is by no means its maximum biological potential, and as yet no attempt has ever been made to attain its highest productivity. With improved methods a higher rate can certainly be secured.

From the above figures we can calculate the approximate productivity of our algal crop and compare it with that of

the higher plants. Imagine an acre of land being flooded with water plus the necessary salts to a depth of one meter and then inoculated with *Chlorella*. In about eight days we can get a population density of 2×10^{10} cells per liter, corresponding to about one gram of dry matter. An acre would give us some 4,000 kg or four tons of dry substance of which more than half would be carbohydrate. If the acre of land were planted to corn, one to one and a half tons of dry matter could at best be obtained in a growing season of 90 days. Thus our alga would be 25 to 30 times as productive as corn. This is not surprising when we consider the fact that the entire body of the alga is photosynthetic, while a large part of the higher plant is essentially parasitic and consumes rather than produces carbohydrates.

Our imagined farm is of course purely hypothetical. There are a number of difficulties to be solved before such a practice could be approached. Light is perhaps not a limiting factor. The organism grows well under an illumination of 4,000 lux which is about one twentieth of full sunlight on a clear summer day. At the depth of 5 to 20 meters of sea water, 5 to 10% of sunlight still penetrates and is more than enough for the algae. Nor is contamination by bacteria a very serious problem if purely inorganic salts are used and the organism can be harvested in a rather short time. Temperature and aeration are important factors. Heating device and air supply must be installed. The growth rate of the organism is yet too slow. It is at best comparable with that of the fat yeast and about one quarter that of the protein yeast. Ordinarily the organism declines to increase when the population density reaches 20 million cells per milliliter or about 1/100 the density of the food yeast. This phenomenon of saturation is caused by a substance produced during growth and is inhibitory to both *Chlorella* and a number of bacteria. It may be removed by certain absorbents, and upon such removal the alga can attain up to three times its saturation density. Even then the volume of the cultures to be handled is too large to be practical.

So far there are no data available on the nutritive value of this alga. Judging from its chemical composition we may be fairly sure that it does not differ much from the higher plants which we use as animal fodder. In nature the alga forms a part of the plankton flora and is a primary source of food for fishes; so indirectly it is, *ab initio*, a food for man.

This fact leads us to the consideration of using the sea and fresh water resources of organic materials for human needs. Many discussions have appeared on the subject, and more than once cultivation of these resources has been suggested. Over 70% of the surface of the earth is covered with water, and in it myriad forms of life abound. The sea contains all minerals required for life and compares favorably with good garden soil in fertility. The temperature is even. There is no danger of drought. Plants can be grown down to a hundred meters or more where sunlight still penetrates. Acre for acre it is more productive than land. It has been estimated that in nature a half of the total photosynthetic fixation of carbon dioxide into organic matter is brought about by the plankton of the sea. There, indeed, is a rich supply, too attractive to be long neglected. As far as these resources are concerned we are still in the primitive, hunting and picking stage, although in some waters the Japanese have tried the cultivation of certain seaweeds, and recently the British have been experimentally fertilizing the sea with minerals to encourage the growth of plankton. These ventures

may eventually develop into a new system of aquiculture.

As we have stated above, green algae are by no means the only autotrophic organisms capable of synthesizing carbohydrates. There are many forms of bacteria which reduce carbon dioxide with the energy of sunlight or of oxidation of inorganic compounds. Species of purple sulphur bacteria, for example, can use carbon dioxide and hydrogen sulphide and grow at an enormous rate in light with the accumulation of a great deal of organic matter. Even among the algae themselves there are endless varieties to choose from. With proper selection and breeding there is little doubt that a strain can be evolved to answer the requirements of commercial production.

Many polysaccharides are formed by algae, and some are used commercially in large quantities. Paper has been made from algal cellulose, and agar agar is exclusively derived from algae. Recently alginic acid and a number of phyco-colloids have been found useful in the plastic and coating industries and in food manufacture. Algal carbohydrates may not be all edible, but their possible uses in industry and possibly as raw material for the production of foodstuffs, microbiologically or otherwise, should not be disregarded.

All green plants contain vitamin C in their plastids. Algae are no exception. With suitable methods of extraction they may be utilized as a source of the vitamin in addition to being a supply of carbohydrates.

Discussion

Not so long ago microbes in general were looked upon as fearful enemies of man. Livestock and crops as well as human lives were at the mercy of pestilence and plagues. Microbes have caused more losses than the sum total of all the wars and battles ever fought. Only near the close of the last century was it realized that there are microbes of benefit to man. With increasing knowledge of microbial physiology man not only has gradually brought the harmful ones more or less under control but also has domesticated the beneficial ones and harnessed them to his advantage. They are used to fertilize his fields, prepare his food, manufacture a number of useful chemicals and vitamins and even to make drugs to fight other microbes.

Within the last few years, moreover, it has become increasingly evident that probably all organic material in higher plants and animals can be obtained from microorganisms. From what we have discussed it is seen that from the microbes all the important constituents of food can be successfully derived in respect to both quantity and quality. In addition the microbes offer several more advantages. Firstly they are more efficient in converting material and energy than are higher organisms. Less space and labor and raw material are required to produce the same amount of yield. Secondly they grow fast and give a quicker turnover. Thirdly they thrive easily in an artificial environment, less dependent on natural elements and more amenable to human control. They can be reared in any climate, and there is little danger of natural famine. Modern industrial technology and management can be used with little modification in rearing them. The large-scale production methods that have so successfully revolutionized our industries may profoundly alter our food situation, once they are adapted to the field of agriculture. A major change like this, if effected, will certainly permeate into every phase of human activity and bring about social and cultural readjustments that we can at present hardly surmise.

Of course, we are still very far from

any realization of this condition. The practice of microbial farming is still in its infancy; nay, in the prenatal stage. There are many problems to be solved before it can occupy any significant place in our present system of agriculture. The technical problems are perhaps the least difficult. There are innumerable varieties of microbes awaiting our selection and breeding and a vast store of industrial and scientific experience to draw upon. Questions of food habits and of social adjustment are more difficult to meet, but even these are not insurmountable.

Agriculture has a long past and so far has undergone little change. When man first appeared, the earth was already well stocked with higher plants and animals. Naturally it was these higher forms which he hunted and collected and later domesticated. Nearly all of our important crops and our cultivation methods have a long history, so long that their origins are more or less obscure. Although we have made many improvements and discoveries, especially in recent years, we are yet not very much better off than our ancestors in the face of drought, flood and other of Nature's whims, and have not rid the world of the spector of starvation. Agriculture is still restricted geographically and at the mercy of the natural elements. No radical progress such as we have witnessed in industry has ever been approached in it. A large part of these drawbacks is traceable to the intrinsic nature of the plants and animals we have chosen to employ. Of over a million species of living organisms known to science, not more than a few hundred are utilized for intensive cultivation. With our modern knowledge of the activities of so many more organisms there is little excuse for us to stick to the few old forms for our sole subsistence.

One of the primary aims of science and technology is to enable man to be less dependent upon nature. Some vital transformations have already been duplicated in the laboratory, and a few patents have been issued on microbial synthesis of foodstuffs. But we are a long way yet from our goal. Before that goal can be approached the use of microorganisms must receive extensive investigation. Quite a few physiological processes of the higher organisms have been studied via microorganisms to a successful physio-chemical interpretation. Carbohydrate metabolism and respiration are good examples. The study of photosynthesis is already on the microbial level and is gradually on the way to a biochemical stage. And between the present practice of agriculture and the ultimate chemical synthesis the gap may well be bridged by a period of microbial farming.

Utilization Abstract

Hardwood Pulp. Hardwoods, heretofore, have been of only secondary importance in the production of paper pulp and have been used only as filler in the manufacture of high-grade printing paper. In 1946 wood from such trees as maple, beech, birch and poplar accounted for only 16% of pulp consumption and inventory. This secondary position is accounted for by the short fibers of hardwoods, as compared with those of coniferous trees, but government scientists in the National Bureau of Standards have announced possible 75% increase in the use of short-fibered woods for pulp by addition of the synthetic resin, melamine formaldehyde. (*Anon., Pulp & Paper Bull. 6*(*5*): *1. 1948*).

Watermelon Breeding

The application of breeding technique to improving watermelons has been directed toward obtaining disease-resistant varieties and not toward improving other qualities.

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Introduction

OVER 50 percent of the watermelon acreage of the United States is located in three States—Georgia (27 percent), Texas (16 percent), Florida (15 percent)—with the remainder scattered in North and South Carolina, Missouri, Virginia, Iowa, Mississippi, Tennessee, Oklahoma, Arizona and California. Other States grow less than one percent (36).

Although all varieties of watermelons are generally considered to belong to *Citrullus vulgaris* Schrad., great variation occurs within this species, ranging from small, hard, bitter and inedible fruits to the large, succulent, sweet fruits that make watermelons one of the first ten commercial truck crops in this country. There is no adequate classification or cataloguing of the many types and varieties within the species, and such classifications as we do have are so broad as to be almost worthless.

What do we want in a watermelon? In the past we have classified melons on their ability to withstand long distance shipping, on their quality, on their shape, sometimes on their size. These are outward characters, and without consideration of many other factors we are likely to have a melon that can be shipped but that is low in quality, or we can have high quality associated with too low a plant vigor to be produced economically. It is because we have based our evaluations of varieties on too few characters, usually of the fruit itself, and from too restricted a viewpoint, that the history of the watermelon industry, since large shipments to northern markets began in the 1890's, has been a jumble of varietal names. Most of the varieties of 40 to 50 years ago have disappeared, such as McIver, Phinney's Early, Kolb Gem, Duke Jones, Ruby Gem, Green and Gold, Mountain Sprout, Mammoth Ironclad, Ruby Gold, Sugarloaf and Cole's Early. A few, like Florida Favorite, Rattlesnake and Irish Grey, still can be found in seed catalogues but are of minor importance. The Kleckley Sweet, introduced in 1887, and the Tom Watson (1906) are two varieties that are listed in seed catalogues selling seed in the South, but their popularity is on the wane. Any variety, new or old, that is to maintain its position must possess a satisfactory blend of the many factors that go to make a fine variety. Unless vigorous precautions are taken, a variety can deteriorate under ordinary conditions of propagation, and it is likely that a number of varieties that have disappeared have deteriorated. To prevent this, improved methods of maintaining stocks, and seed certification may help. However, there seems to be no established types for the run-of-the-mill variety, and ordinary mass selection from year to year may basically change the nature of a variety within less than a decade, as seems to have occurred in the variety

Stone Mountain. Such changes within a variety may lead to re-naming with a consequent increase in confusion. Witness the large number of names by which the Florida Giant or Cannon Ball is known today; some of the strains of this variety differ in some important characters, and a study and classification of the various strains needs to be made. Market preference and change occur, often difficult to explain. For years Florida grew the long, cylindrical Tom Watson variety and others like it; then almost overnight the round to short-round Cannon Ball became the favorite, and the long type melon was supplanted.

What may be an ideal watermelon from one viewpoint may be very different from another angle. That is, the plant breeder, the seedsman, the grower, the wholesale buyer and the final consumer may not always agree, and each is apt to want different things, all of which may not be possible to combine under one skin. Often we have to sacrifice one thing to get another, and our failure to appraise varieties has resulted in a great many varieties, each having a few good points but also marked defects. Many seedsmen would like to eliminate some of these varieties but seem unable to agree which will get the axe. We need a series of standards by which to judge a variety, and a brief summary with that purpose in view may not be out of place here. There may be omissions, and not all of the points are of equal importance, but a satisfactory compromise of most of them is necessary.

Watermelon Characters and Their Inheritance

The various characters that go to make up a variety may roughly be grouped under fruit characters and plant characters. Although plant characters often may determine fruit characters, a distinction is made because the plant characters are more general and may be hard to determine without a considerable amount of detailed work. On the other hand, fruit characters are specific and are easily determined by observation.

Fruit Characters. The main characters by which melon fruits are distinguished are size, shape, color and marking, thickness of rind, texture of rind, color of flesh, texture of flesh, uniformity, flavor, sugar content, seed size, seed color and number of seed. Some decision concerning each of these points must be reached, keeping in mind the purpose for which the melon is intended and the conditions under which it is to be grown.

The shape of a long melon should be a cylinder with ends square and well filled. For a round melon a slight "squareness" of the ends generally is liked. A number of years ago the demand was for a large melon, the larger the better; then came an era when a smaller melon was asked of the breeder, a melon adaptable to small families and small refrigerators; and today the demand seems to be again as it started, the bigger the melon the better. Even within a single State, at the same time, the demand can differ; Central Florida wants big melons, while around Tampa the Cuban population wants a relatively small, 12–15 pound melon, and a trucker peddling a load of big melons there has trouble disposing of his cargo. Uniformity in shape and size are more important than excessive sizes with variation of both size and shape. McKay (17) has shown that oblong and round shapes in melons seem to depend on single factor differences, while Porter (33, 34) believes that the inheritance of fruit shape is complex. Weetman (54) gives data to show that the difference between elongate and spherical fruits is determined by a single pair of genes

which lacks dominance. Heterozygous individuals bear fruits of intermediate form. The shape of the mature fruit and young ovary shape were closely correlated. The small size of a mature fruit seemed to be dominant over large fruit, if data for fruit weight were plotted arithmetically, but if the data were plotted logarithmically the genes for size seemed to lack dominance and had proportional effects. Fruit shape and fruit weight were significantly negatively correlated. Poole *et al.* (22) have found that fruit shape and plant sex habit are linked with a cross-over value ranging from 0.136 ± 0.029 for a backcross population of 140 plants, to 0.207 ± 0.010 for segregating F_3 populations totaling 2,085 plants, to 0.350 ± 0.035 for an F_2 population of 301 plants. Fruit shape and fruit weight were significantly correlated in some crosses and backcrosses, but in others the two characters showed no significant correlation. Multiple-factor determination of weight prevented their making linkage estimates. The number of genes segregating for weight inheritance in the cross, Northern Sweet (about 3.2 kilos) × Dove (about 8.0 kilos, heterozygous for weight), was estimated from the F_2 population at 25 genes and from the backcross to Northern Sweet at 12 genes. Weetman (53) has shown that it is possible to forecast the mean shape of watermelon fruits by averaging a number of cotyledon indices, but that the probability of making accurate predictions for individual plants is considerably smaller. Round melons seemed to produce round shaped cotyledons, and more elongate cotyledons were correlated with elongate melons. With citrons there was no correlation, negative or positive, between cotyledon shape and fruit-shape, and in a group of watermelon-citron hybrids the coefficients were not significant.

The chief points to be considered in connection with the color and markings of watermelons are the market preferences, the type the growers have become accustomed to, and more especially the relation of color to the likelihood of sunburn. Ordinarily it may be said that the darker the rind the more the likelihood of sunburn and *vice versa*, but some of our light-skinned melons also burn rather easily. There is a definite prejudice against the lighter colored rind (*e.g.*, the Hawkesbury) in some sections, while in other sections this color is preferred over all others (*e.g.*, the Smithfield area of Virginia). Porter (33) has found that green fruit skin is dominant over yellowish white but incompletely dominant over striped and yellowish green, while Weetman (54) reports that dark-green rind is dominant over light-green rind by a single factor difference, though other genes appear to determine minor variations in the light color; broad striping seemed to be due to a single recessive factor in one cross, but was dominant in another cross. The gene for striping either forms a multiple allelomorphic series with the genes for dark- and light-green rind color, or is closely linked with these genes. McKay (17) observed what he thought was a 3 : 1 ratio in the case of "green stripe" *vs* "white-stripe" melon fruit markings, but further work was considered necessary.

Thickness of rind is rather variable, but the aim should be to produce as thin a rind as possible consistent with the ability to stand handling and shipment. While the rind must be thin, it must also be tough; one easily cut with average pressure from a thumbnail is not tough enough under ordinary conditions. A half inch of extremely tough consistency is about the ideal, but this would also call for great improvement in handling in the field. Melons often are handled as if they were pulpwood; and such handling may result in many melons becom-

ing pulp unless they have a number of the characters of wood. Porter (33) has shown that tough rind is dominant over tender rind, a single-factor difference being indicated from a 3:1 segregation in F_2.

The ideal flesh color of a watermelon to most people is deep rich red, but there is a wide range from brilliant red to yellow. Yellow fleshed melons do not have a general appeal, but some people like this type of flesh. The writer recently has seen a shade given a local name of Flaming Delicious; the flesh has the appearance of half-cooked steak with a dash of orange added. Bennett (2) states that red flesh color appears to be dominant over white flesh color, but in his F_2 there appeared more white-fleshed individuals than expected, and the backcross to the white parent gave all white-fleshed fruits. Porter (33) states that red flesh color is dominant over yellow and suggests the symbol "R" for red and "r" for yellow.

Texture of the flesh is as important as the color. Some varieties are grainy, some rather slimy, and it is the work of the breeder to secure a blend of characters that will satisfy as many people as possible. Crispness and freedom from stringiness are perhaps the main requirements. Bennett (2) could find no evidence of the inheritance of flesh texture in watermelon, and Porter (25) believes that the flesh quality of citrons resistant to Fusarium wilt is dominant over the flesh quality of the wilt-susceptible watermelon, as Orton (19) had stated previously. There is considerable range of variation in the uniformity of flesh in regard to both color and texture. In some melons the range is all the way from small, hard areas within the flesh to whiteheartedness and inedibility. It is probable that much of the whiteheart of melons is due to genetic rather than environmental causes, but of course this should be qualified on the basis of the definition of whiteheartedness. The so-called "second growth" of watermelons should not be confused with whiteheart. "Crackleheart" may occur also to a greater extent in some strains than in others and must be guarded against. Its origin is poorly understood, but it is possible that both environmental and genetic factors are responsible. Round varieties seem to show this defect more often than long varieties, and it is possible that the difficulty may be to some extent mechanical in that distribution of weight is less efficient in round types. Walker (46) reports that whiteheart was present in the Kleckley Sweet out of which he selected the wilt-resistant Leesburg; melons showing whiteheart were discarded, and the Leesburg is free of this defect, as is the Blacklee, while the Hawkesbury, the other parent of the Blacklee, shows much whiteheart (51).

Flavor in watermelons in judged largely on the basis of sugar content, but different flavors do occur and some are objectionable but relatively easy to eliminate. The sugar content is more important and takes continual testing to assure that the variety possesses a total solids content of more than nine percent when mature; the higher quality melons will range between ten and twelve percent, sometimes reaching sixteen percent. Sugar content does not necessarily have to be associated with flesh color, since tests on relatively immature melons can show rather high refractometer values. This might be an advantage when melons are marketed before complete maturity. Porter *et al.* (35) found that real differences in sugar content exist among melons, with Leesburg and Hawkesbury relatively low in California and the Klondike types relatively high. Eighty-five percent of the total soluble solids is sugar, and it is justifiable to use the hand refractometer to determine relative sweet-

ness of juices of melons. Two or three drops of juice taken from the blossom end of one-half of a fully mature fruit, between the rind and the seed zone, gives approximately the same refractometer reading as a composite sample taken from the edible tissue located almost entirely within the seed zone of the same half. The center of a melon has a soluble solid content roughly 1.3 percent above the average (16). Reducing sugars are formed first in the watermelon, and with approach of maturity sucrose development proceeds rapidly (35). Sucrose predominates in overmature or mature stored fruits. Of the reducing sugars, levulose predominated over dextrose in limited tests; later dextrose increased more rapidly than levulose. Varieties possessing relatively low soluble solids and total sugar content on the average contain individual plants which produce high sugar fruits.

There is a wide range in the size of seed in melons, and little effort has been made to breed to any particular size. From the consumer's standpoint he would just as soon have as few seed as possible. The color of the seed is a matter concerning which there is more difference of opinion; darker seed usually are preferred and a red flesh color is intensified by the presence of dark colored seed. Some persons believe, incorrectly, that lighter colored seed, white or tan, are signs of immaturity or crossing with citron. Another rather wide range is the number of seeds produced by varieties, and a somewhat high price charged per pound can be traced in certain instances to the production of relatively few seeds per melon. Environmental influences are said to determine the number of seeds produced, but experimental evidence is lacking. Poole *et al.* (21) in a well-rounded study found that seed coat color ranges from an almost pure white through red, green, tan, mahogany and black, with various patterns superimposed. Their new term "clump", referring to seed color, means a phenotype which varies in segregating populations from a large central eyespot to nearly uncolored seeds except for black spots on the hilum prominences. They studied black, clump, tan, white-tan-tip and white-pink-tip seed color phenotypes, and of ten possible cross combinations seven were made. Analysis of F_2, F_3 and backcross populations indicated that the colors and patterns of this series were determined by the interaction of a system of three main genes, R, T and W, and one specific modifier, D, operating on black only. Of the eight possible phenotypes from the three main genes, six were indicated, *viz:* RTW (black), RTw (clump), RtW (tan), Rtw (white-tan-tip), rtW (red) and rtw (white-pink-tip). RTWd restricts the black pigment to dots more or less uniformly distributed. There was no evidence of linkage within groups of the length (LS) or color (DRTW) genes; but between groups, the genes L and W displayed coupling linkage of 19.3 ± 1.1 in F_2 and 15.8 ± 1.2 in back cross, 24.7 ± 4.9 repulsion linkage in F_2, and 21.52 ± 7.24 coupling linkage among the two completely identified parents of an F_3 generation. The previous works of Kanda (12) and Weetman (54) support these findings. Other works on the inheritance of seed color are by McKay (17) who showed in two crosses, tan × red and green × red seed coat, that the red color is recessive and controlled by a single factor difference, and by Porter (33) who reported that black and tan seed coat each are dominant over white, black is dominant over tan, red seemed to be dominant over white, and both black and red seemed to be dominant over green. The number of factors involved was not determined. Weetman (54) crossed races of melons wherein

weight samples of 25 seeds were light (1.22 ± 0.01 gm.) and heavy (2.60 ± 0.05 gm.). In the F_2 and backcrosses to both parents the lighter weight parent approached monogenic dominance over the heavier, but chi-square analysis failed to establish an acceptable fit. Poole *et al.* (21) found that watermelon seed length can range from 5.5 to 15.5 mm. Three seed-length phenotypes were studied, short (average about 6 mm), medium (average about 10 mm), and long (average about 13 mm), which behaved with respect to each other as though belonging in a dihybrid F_2 segregation of nine medium (LS) to three long (lS) to four short (Ls and ls). Weetman (53) calculated an index for seed shape and showed that melon varieties with round fruits have seeds which are less elongated than those from long-fruited varieties.

No evidence of linkage has been found between flesh color and seed coat color, between flesh color and fruit rind color, between flesh color and rind toughness, between fruit-skin color and rind toughness, between seed-coat color and rind toughness, or between skin color and seed coat color (33).

Plant Characters. The chief points are vigor, earliness, prolificacy, and resistance to disease, insects or mechanical injury. Vigor may be defined as the ability of a variety to thrive under a wide range of environmental conditions, the aim being to secure strains or varieties that show an ability to survive without special care. It may take a long time to gain definite information on what constitutes earliness, which is of great importance in early market sections (Florida, Georgia), but no variety, to succeed, must be conspicuously later than others grown in the same geographical area. Earliness may be associated with vigor, and this might also be said of prolificacy. In some instances a variety may be overly prolific, *e.g.*, the Blacklee, and require heavy "pruning" which is expensive, with the possible introduction and certain spread of plant diseases in the process.

Inbreeding of the watermelon does not cause loss of vigor, self-sterility, decrease in number of fruits, or total yield per plant (28, 31, 46, 51), and tends to isolate strains which produce either larger or smaller fruit than the commercial variety, and to establish homozygosity for those factors responsible for rate of plant growth (31). In the Klondike variety, strains inbred for four successive generations have been isolated which produce fruits equal in weight to those of the parent variety but which excel the latter in fruit uniformity, flesh color, texture and quality (28). In 1947 the Iowa Agricultural Experiment Station released two melon varieties, the Dixie Hybrid and the Kleckley Hybrid, both F_1 seed, the former wilt-resistant, the latter possessing "strong resistance to wilt and anthracnose". It is pointed out that seed of these melons should not be saved, since they do not reproduce themselves. The two varieties were grown at Leesburg in 1947, and some wilt occurred in the Dixie Hybrid which is a large, well favored and tasty melon; the Kleckley Hybrid, late to mature and rather small, showed more anthracnose than Black Kleckley and was not tested for its resistance to wilt. This is probably the first instance of the usage of hybrid seed in watermelon. Porter (31) and Walker (49) have described the techniques valuable in watermelon breeding.

Rosa (37) and Porter (33) have shown that in crosses between monoecious and andromonoecious varieties of watermelons, the monoecious condition depends on a single dominant factor. In watermelons and citrons the monoecious condition predominates, and only a few (Black Seeded Angelino, Black Seeded

Chilian, Snowball, Winter King and a Kalihari citron) have been found to possess hermaphroditic flowers. The factor concerned in sex differentiation must be borne by both micro- and macro-gametes, since reciprocal crosses and back-crosses give concordant results (37). Pistillate flowers usually have a long ovary, while hermaphroditic flowers have shorter, more nearly round, ovaries. Kozhukhow (13) reports 11 pairs of chromosomes for several varieties of commercial watermelons, and Bennett (2) confirmed this figure.

Fruit setting tendency, following artificial self-pollination, is apparently influenced by the air temperature and humidity between 6 A.M. and noon, by the hour of pollination, by ovary size and by the relative vigor of the runners bearing the selfed flowers (31). Relatively low air temperature and relatively high humidity from early morning until noon favor fruit setting. A better set is obtained if pollinations are made between 6 A.M. and 9 A.M. than between 9 A.M. and 12 noon. Small ovaries rarely set fruit, while fruit setting tendency progressively increases among large ovaries. Strong or medium runners bear large ovaries. There is no evidence that fruit-setting tendency, after self-pollination, is heritable; it depends entirely upon proper selection of the pistillate flower with respect to ovary size and runner vigor and on the environmental conditions for a period of five or more hours after pollination. No evidence was found of flowering peaks or fruiting cycles, such as have been reported for muskmelon and for squash.

Resistance to disease is highly important, and we now have a number of wilt-resistant varieties (see: Fusarium Wilt), and at least one anthracnose-resistant variety (see: Anthracnose), but no known varieties resistant to gummy-stem blight or downy mildew. Resistance to aphids will be acceptable when found, and resistance to the attacks of the root-knot nematode could be used. Under the heading of mechanical injury must be considered sunburn which can severely injure an otherwise beautiful crop of melons. Sunburn in Florida seems to occur under conditions of high temperature and high humidity; the small area of melon rind uppermost literally burns and dies, leaving a yellow blemish which can serve as an avenue of entrance for rot-producing organisms. Locally we have found that a lime wash or paint, applied to the uppermost strip of tissue of the melon, not more than three inches wide, will at low cost reduce or inhibit burning. Its removal is easy with a dampened rag. Excessive or repeated rains may wash off much of the lime, but it can be replaced even more rapidly than originally applied. Failure to show much sunburn is one of the good points about the variety Cannon Ball.

The most elusive factor in melon breeding is the matter of market preferences in which the range is about as great as the number of consumers, and it often is difficult to fix upon definite standards because of the constantly changing demands of both grower and consumer. Even with the best of varieties, seasonal conditions or diseases may undo the most careful work of the breeder or seedsman. With the improvement of varieties and of seed there also should be an accompanying improvement in field practices, particularly in disease control and handling.

Even though a happy blend of most of the varietal characters is attained, the problem arises as to how to maintain the variety unchanged, or at least prevent its deterioration. It is not possible in most cases for wholesale seed growers to assume full responsibility, since few are in a position to maintain breeding fields where close attention can be paid

to a single variety. About as far as they can go in this direction is their cooperation in carrying out a satisfactory certification program. Where disease-resistant varieties are concerned, a lack of detailed knowledge of the diseases involved would be an especial obstacle. Without sacrificing the more detailed work of varietal testing and improvement it is not possible for State experiment stations to maintain indefinitely stock-seed fields of standard varieties or of new introductions. While much work is being done toward improving varieties and seed, no long time provision has been made to assure the maintenance of stocks we now have and the ones that will appear in the future. It seems that some provision of this kind is needed, one that would serve as a repository for unquestionably pure and true types of standard and recognized varieties and strains. Testing and accurate appraisal of all stocks would be made before recognition. Maintenance of such stocks certainly would simplify seed certification. In the meantime, certification of seed, purification of stocks, elimination of the less desirable strains, development of new strains and the improvement of older ones are going ahead in various parts of the nation.

Breeding For Disease Resistance

When one examines the literature on watermelon breeding, two things immediately focus the attention, one, that most of our knowledge of the inheritance of characters in watermelon has been obtained by plant pathologists or plant breeders interested in the development of disease-resistant watermelons, and second, that the States most interested in the production of resistant varieties are the States that have contributed to our knowledge of the genetics of watermelon. Because a variety not only must be resistant to disease but must also possess high quality and be desirable in type, the watermelon breeder usually has studied the factors that determine quality and plant type simultaneously with the mode of inheritance of disease resistance. In a few cases horticulturists, geneticists or plant breeders have studied the watermelon *per se* (12, 17, 37).

Investigators have striven to develop varieties resistant to wilt, caused by *Fusarium oxysporum* f. *niveum* (E.F.S.) Synder and Hansen, and to anthracnose, due to *Colletotrichum lagenarium* (Pass.) Ell. & Hals. Other diseases that would appear susceptible to control through breeding are downy mildew, caused by *Peronoplasmopara cubensis* (B. and C.) Rost., and gummy-stem blight, due to *Mycosphaerella citrullina* (C. O. Smith) Gros.[1], for differences in susceptibility do exist.

Fusarium Wilt. The fungus *Fusarium oxysporum* f. *niveum* (= F. *niveum*) was first associated with watermelon wilt by Erwin F. Smith in 1894 who studied the disease in South Carolina (41). Later Smith (42) found the macroconidia and chlamydospores, and in 1899 he gave a report on the morphology, vitality, longevity, pathogenicity and dissemination of the causal agent, a description of some of the seedling and field symptoms, and an account of the relation of the fungus to the host (43).

Wilt-resistant Varieties. Orton's research (19) is a classic example of the early work in this country in the development of disease-resistant plants. His Conqueror variety, produced in eight generations from the cross of the wilt-susceptible, edible variety Eden with the wilt-resistant, inedible citron, seemed to be highly resistant at first, but subsequent testing showed that its disease-re-

[1] A recent paper (Chiu, W. F. The pathogenicity of *Mycosphaerella citrullina*. Phytopath. [Abst.] **38**: 5. 1948) states that Improved Kleckley Sweet is more resistant than Hawkesbury.

sisting powers were lacking in Iowa (25, 26, 27, 30), West Virginia (39, 40) and Oregon (40). It was highly resistant, however, in Texas (44), but its type and quality there were not entirely desirable (26, 44). Today the Conqueror seldom is grown. Orton did demonstrate, however, that the citron melon possessed resistance to Fusarium wilt, and this lead was adopted by investigators in Iowa, California and elsewhere.

In 1924 the Iowa Agricultural Experiment Station initiated a program to develop watermelon varieties resistant to Fusarium wilt which had wrought so much damage, particularly around Muscatine, that fields once producers of good crops had been idle for 16 years. Land values there dropped materially and the watermelon section lost its air of prosperity, a condition that was charged directly to watermelon wilt (26). The disease is said to have reduced the average annual Iowa acreage by 90 percent and the average annual shipments from about 3,000 to less than 50 carloads (30). Porter and Melhus soon recognized that in every infested field a few plants of the varieties Kleckley Sweet, Excel and Long Light Icing did not wilt (30), and in 1927 they planted a large field of the Kleckley Sweet on infested soil, out of which 11 selfed melons were obtained, and one of these, the K-S4, became the Pride of Muscatine. This variety, while it served to tide over the Iowa farmers, was not desirable in type and had a rather inferior flesh (34, 56). By further selection and inbreeding of another strain from Kleckley Sweet, the K-11, the variety Improved Kleckley No. 6 was isolated and introduced around 1936. Out of the cross Stone Mountain × Japan No. 7 (a wilt-resistant, round-fruited, yellow-skinned, white-fleshed variety) was developed the wilt-resistant Improved Stone Mountain No. 5 (23) which is adapted for local marketing and home use rather than for shipping because of its tender rind. Two other wilt-resistant varieties, the Iowa Belle and Iowa King, were developed in Iowa during a three-year period prior to 1931. Both of these were chance hybrids out of Orton's Conqueror which had been subject to pollination by other varieties, particularly the Kleckley Sweet, picked up in the field by O. H. Elmer and S. M. Dietz and turned over to Porter and Melhus for further study (30). Both Iowa Belle and Iowa King are long type melons; both mature later than Pride of Muscatine. Layton and Wilson have shown that Pride of Muscatine, Iowa Belle and Iowa King give good yields on Fusarium-infested land (14).

Continuing his research at Iowa, Porter (25) reported that some Chinese selections, Preserving Citron, and two selections of forage melons from Africa possessed resistance to wilt and were being utilized as parents in his breeding program. At about the same time Sleeth (40) was finding that a Russian variety of melon was almost immune from wilt. Porter and Melhus (27) then tried crossing the Conqueror melon with the Kleckley Sweet and reported that the F_3 of some of the crosses appeared to possess considerable resistance. They noted, however, that the Conqueror showed little resistance, and this confirmed previous observations that resistance was present in the Kleckley Sweet; Walker (46) corroborated this, and his Leesburg is a selection out of Kleckley Sweet. Porter and Melhus (27) also tested the resistance of seven citron strains, finding that six were immune from wilt and that in the F_3 of the cross Kleckley Sweet × Citron (variety Kafir) there was 86 percent resistance, but few of the melons were edible.

In the meantime the watermelon growers of central Florida (Lake County) had secured an appropriation from their

legislature to establish a research laboratory at Leesburg to develop a melon or melons that would resist Fusarium wilt. The predominant variety in 1930, the year that the Watermelon Laboratory was started at Leesburg, was Tom Watson, which is a high quality, cylindrical, dark rind variety with brownish seeds. Florida melon growers were afraid that they would soon exhaust their supply of "new land", or their supply of land which had not supported melons for eight to ten years, that is, land on which a wilt-susceptible variety could be grown. Clearing and fencing new land each year involves heavy expense (over $40.00 per acre in 1946), and, as the fields become located farther from the highways and railroads, there is also an increase in the costs of transporting equipment, labor and the crop. Walker (46) stated in 1936: "The continuous use of new land in the Leesburg area has practically depleted the supply and, unless a marketable, resistant variety is grown, the industry in this particular area must decline". This did not turn out to be so, however, and even today the watermelon grower of central Florida seems to be able to find "new land" on which to plant his wilt-susceptible favorite variety, the Cannon Ball or Florida Giant. Walker (46) pointed out further that the wilt-resistant varieties developed by the Iowa Station were not suited for Florida growing and marketing conditions, which necessitated the production of a wilt-resistant variety for Florida. He tested the wilt resistance of 104 varieties and strains of watermelon and also a few citrons. To speed up the work of strain elimination, greenhouse testing of resistance to wilt was carried on simultaneously with field work. By 1936 Walker had eliminated all but about 12 strains of melons, one of which was the high-quality, wilt-resistant Leesburg variety, obtained by selection from the Kleckley Sweet, seeds of which had been obtained from a Leesburg seedstore (46). The Leesburg is of a lighter color than the Kleckley Sweet but with a tougher rind, long, with blocky ends, smooth, faintly grooved, medium dark green. The seeds are white. It was free of whiteheart and did not sunburn too much, averaging 22 to 26 pounds in weight, occasionally reaching 30 to 35 pounds.

Unfortunately the Florida watermelon growers did not like the Leesburg variety; they said it was too small, the flesh was pale red instead of red, and it had white seeds, qualities which are objectionable because they often are considered to indicate immaturity. So, with plenty of "new land" available, the Leesburg went unused locally, but it was tried in Virginia (4, 5), Oklahoma (3), and California (34), and was found to be highly resistant. In none of these places, however, was it the type required and it could not compete with varieties like the Hawkesbury or the Klondike. Seedsmen in north Florida still grow Leesburg seed which they market in Florida, Georgia, Mississippi, Maryland and Virginia, but they sell only about 10 percent of the seed they sold in 1942. The Hawkesbury had been discovered in Australia in 1935 (59, 60), growing in a field of Grey Monarch melons, by Mr. H. S. Shirlow, the plant breeder at the Hawkesbury Agricultural College, Hawkesbury, New South Wales. Since it differed from the regular Grey Monarch in that it had dark instead of light colored seed, it was first named "Dark Seeded Grey Monarch". Later it was identified wrongly as the Thurmond Grey variety and because of its resistance was designated "Wilt Resistant Thurmond Grey". Subsequently it was found to be different and was named "Hawkesbury Wilt Resistant" or "Hawkesbury". First to receive this wilt-resistant variety in America was Duke Layton at Iowa, and from Layton it was sent to H. T. Cook at

Norfolk, Virginia. Cook (4, 5) and Cook and Nugent (6) confirmed that the Hawkesbury is highly resistant to wilt, as did Walker (51) who used it to cross on Leesburg to obtain the Blacklee, and others (3, 34, 38). Porter (34) reports that he isolated a wilt-resistant white-seeded strain of Grey Monarch in 1930, but it was of inferior quality. Continued inbreeding of more desirable resistant individuals found in Grey Monarch resulted in the production of a strain with 68 percent resistance. Cook (4, 5) and Cook and Nugent (6) were pleased with the performance of the Hawkesbury on wilt-infested land in the Smithfield area of Virginia, but less pleased with the varieties Leesburg, Pride of Muscatine, Iowa Belle, Iowa King, Improved Stone Mountain No. 5, Improved Kleckley Sweet No. 6 and the wilt-resistant strains of Klondike that Porter was developing for the California melon growers. The Smithfield growers like large grey melons, so the Hawkesbury suited them perfectly.

About 1931 Porter left the Iowa Agricultural Experiment Station and went to California which needed wilt-resistant watermelon varieties. The Klondike is their most desirable variety, an oblong to long melon, black-seeded or brown-seeded, depending on the particular strain encountered, with slightly ribbed, dark-green rind, which originated about 1908 as a mutation in a field in southern California (31). A variation of the Klondike is the Striped Klondike which has a light-green rind with darker-green striping, said to have been selected about 1923 in a field of commercial Klondike. To develop resistance to Fusarium wilt in the Klondike, Porter (34) planted a wilt-infested field with approximately 200,000 seeds of the variety obtained from as many sources as possible. Sixteen plants survived, and self-pollinated seed was saved from nine plants which were used as subsequent breeding stocks; in 1937, after two years testing, only a single strain seemed worthy of further propagation ("Pedigree 24"). This strain, later termed "Klondike R 16," showed high resistance in California, Iowa, Florida, Georgia, Virginia and Indiana. The flesh texture left something to be desired but this defect was not pronounced in Georgia and Florida. In greenhouse work a large number of plants of the susceptible Klondike were grown in wilt-infested soil; 12 plants out of 2790, or less than 1 percent, lived, and but a single strain was obtained with a high resistance which was inferior in quality to Klondike R 16. Porter next tried hybridizing commercial Klondike and the inbred Klondike lines initiated by the late Dr. J. T. Rosa with the resistant Conqueror, Pride of Muscatine, Iowa Belle and Iowa King, of which Iowa Belle proved to be the most valuable parent. From the cross Klondike × Iowa Belle came "Klondike R 7" which was distributed to California growers when in its F_7 generation; in addition to wilt-resistance, both Klondike R 16 and Klondike R 7 possess a higher sugar content than commercial Klondike (35). With their release the problem of controlling Fusarium wilt of watermelon in California was licked.

In Florida the problem has not been so easy of solution, and today the melon growers have no wilt-resistant variety that they like and will use. As soon as Walker realized that his Leesburg was not liked, even though highly resistant to wilt, he crossed it with Hawkesbury. Both parents being resistant to Fusarium wilt, it was possible to select for horticultural characters in the second generation. By 1942 the new variety, the Blacklee, a long, relatively large (25–30 pounds), dark green, faintly grooved melon with seeds that appear to be jet black when wet but on drying show themselves to be densely stippled with black,

a character rather unusual in watermelons, of superb quality, and 70 to 75 percent resistant to wilt, was released to growers; in 1944 came the official description (51). Sometime prior to 1937 there appeared on the watermelon scene a variety which has been variously termed Cannon Ball, Florida Giant, Clara Lee, Black Diamond, *etc.*, a short-round to round, thick-rind, faintly to markedly grooved, rather large (30–40 pounds), dark-seeded variety of marked earliness, a feature which endears it to growers in Florida and elsewhere in the southeastern States. In comparative tests, Cannon Ball, as it is most generally termed in central Florida, will outperform Tom Watson, Dude Creek, Dixie Queen, Garrison, Leesburg and Blacklee by seven to 14 days, depending on the season. The Blacklee seems to be at its best in seasons of low rainfall, perhaps because of its wilt-resisting character, but year after year the Cannon Ball, which does not sunburn as easily as Blacklee, is preferred, though there is no question but that the Leesburg × Hawkesbury progeny is superior in quality of flesh. In 1947 less than 100 acres of Blacklee were planted in Florida. Elsewhere Blacklee is liked, and its high quality and wilt resistance are used by growers in the Carolinas, Virginia, Maryland, Missouri, Oklahoma, Arizona, Texas and other States.

Other wilt-resistant varieties, still unreleased, were developed by Walker out of the Leesburg × Hawkesbury cross, the Brownlee, and the Improved Leesburg which resemble the Blacklee except for the brown seeds of the former and white seeds of the latter, and the unnamed 124–402–019 which favors the skin-color of the Hawkesbury. These three varieties, like Blacklee, are late maturing as compared with Cannon Ball. In this connection it may be interesting to report value from selection within an apparently pure line. The Brownlee, already breeding true by 1941, was continued to be inbred for two more years, and in 1943 several selections were made by a foreman unfamiliar with the oft quoted remark, "selection within a pure line is time wasted". This man, Mr. Loren H. Stover, made his selections on the basis of quality and size, but in each case the individual melons happened to be among the first maturing in the field. So, in 1945 there were three strains of Brownlee in the Leesburg melon collection, the original and two selections from it. All three were planted in 1945 by the writer, then new at the Leesburg laboratory, in order to familiarize himself with the melon-breeding records. Both selections are earlier maturing than the original Brownlee which has been discarded, and the present Brownlee consists of bulking of the two selections. This laboratory is now determining whether the Blacklee is a "pure" line for earliness or whether an improved strain can be obtained by selection for this "character", for there seems little doubt that an early Blacklee would be acceptable to Florida growers who some day will have to plant wilt-resistant varieties.

In 1942 the Georgia Experiment Station introduced their Georgia Wilt-Resistant melon, developed by van Haltern (45) out of the cross Cuban Queen × Iowa Belle, which in general external appearance resembles Stone Mountain. The chief objection to the variety is its small size as compared with the larger Cannon Ball. A second selection of van Haltern's is his Georgia Wilt Resistant No. 2 which looks more like a pumpkin than like Stone Mountain, but it is by far the sweetest melon grown, with the exception of the Klondikes. The rind is thin and cracks easily in wet weather. Epps (8) more recently has released the wilt-resistant variety Miles, developed at the Tennessee Agricultural Experiment Station from material sent there from the Mississippi Agricultural Experiment

Station in 1942. The Miles originated from the cross Dixie Queen × Klondike; it is oblong, green with darker green stripes, with a tough rind, white-seeded, 25–35 pounds in size. Another melon variety is the wilt-resistant Dixie Queen which the writer tested at Leesburg in 1947 and found to be about as resistant as the Blacklee, but which was less resistant at Charleston, S. C.[2] This wilt-resistant Dixie Queen is said to have been found in Nebraska about 1943 and is being commercialized by Otis S. Twilley, grower of watermelon seed at Salisbury, Maryland. In 1946 the variety was planted by Mr. W. H. Thomson, seed grower, of Lloyd, Florida, on wilt-infested land where it showed a high degree of resistance.

At Charleston, S. C., in the Regional Vegetable Breeding Laboratory of the United States Department of Agriculture, research developing anthracnose- and Fusarium wilt-resistant melons has been under way for a number of years under the joint direction of C. F. Poole and C. F. Andrus, and lately of Andrus alone. To date no publication has been forthcoming on their results, but this writer, and possibly others, has received seeds of segregating material for trial. At Charleston has been attempted the production of wilt-resistant Garrison and Dude Creek varieties, using Leesburg and Hawkesbury as resistant parents.

Physiologic Strains of Fusarium. While it was thought for a time that different physiologic forms of the wilt fungus must exist (39, 40), since the Conqueror variety was not resistant in all melon-growing areas, present ideas are that pathogenic variation among strains of *F. oxysporum* f. *niveum* probably has not been, to date, a serious factor in the breeding programs undertaken (34). It is significant that Walker (46, 48, 51), in his development in Florida of the Leesburg and Blacklee varieties, does not report the use of isolates of the wilt fungus from other States, yet both varieties are wilt-resistant wherever tested. Sleeth (40) has shown, and Bennett (2) has confirmed, that the amount of wilting produced by a given strain of the Fusarium is not always uniform when tested against different varieties of watermelon. The cause of muskmelon wilt (*Fusarium oxysporum* f. *melonis* Sny. and Hansen) is said not to attack watermelon, nor does the watermelon pathogen attack muskmelon (10), but recently Hendrix *et al.* (9) report that some isolates from wilted muskmelon plants can cause pre-emergence killing and wilting of watermelon seedlings, and some isolates of watermelon parasitize muskmelon. In general, the virulence of an isolate was greater on its original host than on the second host plant, but several isolates from watermelon caused a more severe reduction in stands of muskmelon than of watermelon.

Inheritance of Resistance. Until recently it was thought that resistance to Fusarium wilt is inherited as a recessive character, since F_1 plants become diseased when grown on wilt-infested soil. Segregation of resistance and susceptibility takes place in the F_2 generation, but no one has obtained clear cut or established ratios (2, 19, 25, 30, 48). In these instances wilt resistance was obtained from a citron (*e.g.*, Conqueror) or from the progeny of a citron × watermelon (*e.g.*, Iowa Belle or Iowa King). First clue that wilt resistance might be inherited differently was found by Welch and Melhus (52) who crossed resistant × susceptible watermelons and discovered that the F_1 progeny were not always susceptible to wilt. In one cross, Dixie Queen × (Iowa Belle × Jugoslavia 7 × Iowa Belle), the F_1 were 70 to 85 percent

[2] Personal correspondence with Dr. F. S. Jamison, Horticulture Department, Florida Agricultural Experiment Station, Gainesville, Florida, and Dr. C. F. Andrus, Regional Vegetable Breeding Laboratory of the United States Department of Agriculture, Charleston, S. C.

resistant, and in two other crosses, (Japan 7 × Thurmond Grey and Japan 7 × Dixie Queen) the F_1 were 80 percent resistant. In ten other crosses the resistance ranged from 50 percent to zero with the susceptible parent grown as a check dying 100 percent. Resistance is considered by some to be multifactorial (2, 34; unpublished data by Walker), and because of difficulties incident to this fact no wholly immune or 100 percent resistant variety of watermelon is yet available. The highest degree of resistance seems to be 75 to 80 percent. However, under ordinary field conditions of wilt infestation this is practically 100 percent, as a considerable number of seed are planted and by the time the plants are thinned, most of the susceptible individuals are dead or dying. Were resistance due to a single factor which is inherited as a recessive, then complete resistance should be found in the immediate progeny of a selfed plant of a commercial variety that withstood the fungus. No such case has been reported.

No close linkage exists between resistance to Fusarium and flesh color, fruit shape or color of seed (2).

Measuring Wilt Resistance. It was realized early in the development of wilt-resistant watermelons that information regarding infection by the fungus was inadequate. More had to be known of the symptoms associated with wilt, how to reproduce the disease, and how to test the wilt resistance when obtained. Such questions arose as: "Are results in the greenhouse comparable to results obtained in field tests?" "How many seeds should be planted in a hill?" "In a pot?", and so on.

Smith (43), Taubenhaus (44) and Orton (19), the pioneers in watermelon wilt studies, all described the symptom "wilting", but it remained for Porter (26) to show that the fungus also could cause seedling wilt, seedling rot, damping-off, stunting and root canker, also leaf chlorosis and a shortening of the internodes of diseased vines accompanied by excessive blossoming at the ends of the runners (30). The fungus was found to grow best on artificial media at 24° to 32° C., with a minimum below 12° C., and a maximum above 25° C. (26), and various strains give good growth on agar between 20° and 33° C., but 26° to 28° C. is most favorable (48). In the field mature plant infection is greatest when the soil temperatures are 22 to 27° C., with seedling rot most severe at 16° to 18° C., and seedling wilt most severe at 25° to 28° C. (30). Greenhouse studies (48) revealed that infection of watermelon or of citron takes place between 21.5 and 30° C., with 27° C. the most favorable; seeds rot when the soil temperature is 18.5° C.

A number of investigators have attempted to measure relative resistance of varieties and hybrids in the seedling stage in the greenhouse (2, 30, 34, 40, 48, 58), but to date the techniques used and the results obtained are not accurate enough to be dependable, even though they show general agreement. Often, when melon seeds are planted in naturally wilt-infested soil, such organisms as *Pythium* spp. and the root-knot nematode (*H. marioni*), produce, with the Fusarium, an infection complex which is difficult to separate into its component parts. If steamed, later Fusarium-infested soil is used, virulence may be many times as great as would occur in nature. These data are inadequate to give us a clear picture of the nature of the inheritance of resistance to wilt. Infection in the greenhouse has been obtained by the use of infested soil (26, 30, 46, 48, 58), by means of spore suspensions of the fungus injected with a hypodermic needle into the hypocotyl (26), and by insertion of mycelium into wounds (26). The fungus has been recovered from primary, secondary and tertiary roots, from stems, petioles, leaves, peduncles, and melon flesh and seeds of infected

plants; unfortunately supposedly immune citron vines also have yielded a fungus pathogenic to watermelon, and from the vascular system of outwardly healthy watermelon vines the fungus can be cultured (26). With wilt-resistant varieties that have borne abundant fruit, if individual plants are examined carefully, 100 percent internal infection can be detected, yet such plants outwardly appear healthy, and self-fertilized seed from them will produce resistant plants. If a runner of a plant growing in wilt-free soil is induced to root in infested soil, only that portion beyond the new roots manifests infection. Again, if a runner is rooted in wilt-free soil while the main root system is in infested soil, the rooted runner may remain healthy (34).

Porter (30) found that inoculum was effective when mixed with steamed soil at the rate of 2:700 grams. The soil consisted of a mixture of two parts bench soil and one part river sand, steamed three times at 25 pounds for three hours on alternate days. One half pint of this soil is placed in a four-inch pot, and two grams of finely powdered inoculum of the fungus applied in a thin layer at the soil surface. The pot is then filled to within one inch of the top. Twenty-five surface disinfected seeds are planted and covered with steamed soil. Walker (46, 48) grew plants in the greenhouse and in the field in naturally and in artificially infested soil. In greenhouse work sterilized soil was infested with the wilt organism by mixing with the surface three inches of soil, in pots or cans, approximately a teaspoonful of agar cultures macerated with clean sand, or by adding a heavy spore suspension of the organism from steamed oat cultures, or by filling the upper third of the containers with soil mixed with sand-cornmeal cultures of the wilt fungus. The sand-cornmeal mixture was made up of equal volumes of sand and cornmeal moistened with tap water. The mixture, after cooking in an Arnold sterilizer for half an hour, was rolled into small balls about ¾ inch in diameter and placed in quart Mason jars to about two-thirds their capacity. After pressure sterilization the jars were inoculated with small quantities of a spore suspension of the wilt organism, and incubated two weeks at room temperature. Plants were observed in the greenhouse for 20 to 30 days, taking daily records on the development of wilt. In the field Walker reports that one or more applications of a handful of heavily infested soil to each hill insures good infection; plants were counted frequently during their growth until maturity, and a final check was made at the end of each season by cutting surviving vines and examining for wilt infection (46)[3]. The number of seeds planted per pot and the number of seedlings crowded into a hill can affect the number that die from wilt; the greater the number, the more that die, then the lower the apparent percent resistance (34). Wilson (58) modified the Iowa method (30) for greenhouse testing of

[3] Recent correspondence from Dr. M. N. Walker has this to say: "Since absolute immunity is rare, it is possible that there may be degrees of resistance, that is, a quantitative resistance. This may be determined by the number of genes directly affecting resistance or to indirect effects arising from genes affecting general vigor of the plant or specific response to environment. During my experience in Leesburg when I cut many roots at the end of the season, it was observed that survival could not be the final criterion. That is, the condition of the plants that survived was important. Two strains showing the same numerical survival showed marked differences in the apparent injury as judged by the evidence of infection in the cut roots. The word 'tolerance' is a dangerous one, but it is conceivable that relative vigor of two strains might result in one being able to survive an attack that would kill or seriously injure the other. This also involves a time factor and during several years I observed the seeming recovery of poor plants that hung on until extreme temperatures inhibited the fungus. Such plants would regenerate roots in the surface soil after the deeper roots had rotted off completely".

wilt resistance by planting five seeds of the melon whose wilt-resistance was desired and an equal number of a wilt-susceptible variety in opposite sides of a four-inch clay pot, in steamed soil, in duplicate or triplicate. A level teaspoonful of wilt-infested soil is previously stirred into each pot at the one-third level. The soil inoculum is prepared from steamed soil later heavily dosed with a mixture of Fusarium cultures in which susceptible plants have been grown until all wilted. The seedlings are counted at emergence, six to nine days after planting; the wilting plants, at one to four day intervals, removing the diseased individuals as observed. Wilson believes that a greenhouse technique for testing resistance applicable to one resistant variety may not be equally usable with another variety. In the field the initial stand is considered established after thinning when taking data on wilt resistance, ignoring plants that can die soon after emergence, which may be caused by *Rhizoctonia*, *Colletotrichum* or even *Pythium*.

To answer questions as "Why do infected seedlings in either the field or greenhouse appear healthy just a few hours before sudden wilting and death?", or "Why do older plants in the field suddenly die, appearing as though cut off at the soil surface?", Porter (29) showed that the external conditions of the environment that determine the rate of transpiration from leaves and the rate of evaporation from atmometer cups appear to influence the rate of wilting. Variation in the rate seems to depend on variations in the factors that influence transpiration, *viz.*, combinations of increased light intensity, abrupt or sustained rise in air temperature, low relative humidity, *etc.* The findings of Wilson (58) seem to indicate that a susceptible variety wilts because its plants cannot obtain enough water to compensate for that lost through transpiration, as the wilt fungus has congested the xylem tracheae and smaller vessels of seedlings with mycelium, and of plants 40–90 days old with gum-like materials and tyloses, in addition. Wilted seedlings can be induced to recover by placing them in a moist chamber where no further symptoms develop. Bennett (2) believes that wilt-resistance is a measure not of the failure of the fungus to enter a melon plant via the root tips and ruptures formed by newly emerged lateral roots (58), but of the inability of the fungus to develop sufficiently to produce the afore-mentioned plugging of the xylem tracheae. Older resistant plants withstand attacks of the wilt pathogen that are fatal to seedlings, apparently because a defense mechanism has had time to develop. Just what this defense mechanism is, Wilson (58) does not elaborate. Possibly the greater root-system of the older plant is involved.

Seed Production Of Wilt-Resistant Varieties. As indicated, wilt-resistant varieties are not immune; at best they are only 70 to 80 percent resistant. If growers attempt to produce seed on wilt-free soil or on infested soil on which the production of wilt is not certain, as is said to occur in the heavy soils of west Florida and Georgia, some plants of low resistance will mature a seed crop and also will cross with plants ordinarily resistant. Because resistance is inherited as a recessive character, any seed from these susceptible plants, or any seed from resistant plants that result from fertilization by pollen from the susceptible plants, will produce susceptible progenies in the next crop. Thus growers will receive the impression that resistance is not fixed and that the resistant variety is "running out" or "going back". Seed producers should locate infested soil, on which wilt is expressed, for reproduction of wilt-resistant varieties.

Anthracnose. Anthracnose, caused by the fungus *Colletotrichum lagenarium*

(Pass.) Ell. and Hals, is the worst disease of watermelons in the United States and is found almost everywhere that melons are grown, with the possible exception of California, and its seriousness can be realized from the figures of 20 to 30 per-cent loss reported from some States. It is especially serious and destructive in the southern States; in Florida it causes more loss than all other diseases of water-melon combined, and seldom a season passes without it's being a controlling factor in production. Anthracnose can be controlled by timely applications of fungicide, either by spraying or by dusting, using the old standards, Bordeaux mixture or copper-lime dust, but materials such as Dithane, Tri-basic Copper, Zerlate, Fermate, *etc.* do a better job. The correct time to apply a fungicide still remains to be worked out, and growers could save money by the initiation and development of an anthracnose-forecasting service to give accurate information on when to apply the necessary fungicide. Downy mildew could be included in this forecasting service.

Investigators have been considering the possibility of producing anthracnose-resistant watermelons since 1931 when Layton and Wilson (14) reported that Iowa Belle seemed to show less anthracnose injury in the greenhouse and field than Iowa King or Pride of Muscatine; Sherbakoff (38) recently has found that Iowa Belle, Iowa King and Pride of Muscatine are more susceptible to anthracnose in Tennessee than Stone Mountain. Later, Porter and Melhus (30) mention that Kafir and White seeded citrons possess some resistance, suggesting that this might be inbred with watermelon. In 1937 Layton (15) published that Red Seeded, Kansas Stock and Large Striped citrons were more anthracnose-susceptible than Kleckley Sweet, while the Colorado Preserving, Preserving and Green Seeded citrons were resistant. In addition, five varieties of African watermelon, two inedible and three edible, obtained from the Reverend Rush F. Wagner, Old Umtali Mission, Umtali, South Africa, possessed the "R+" type of resistance wherein infection is limited to small lesions resembling mechanical wounds accompanied by little or no injury, which Layton considered to be the only plant reaction usable for the development of resistant varieties. No similar reaction was found in the wilt-resistant selections out of Kleckley Sweet and Conqueror in the melon collection at Ames. The African melons were wilt-susceptible, but their seed and leaf characters were similar to those of commercial varieties. The three edible strains, Africa 8, Africa 9 and Africa 13, were crossed to the wilt-resistant Iowa Belle and Iowa King, and by greenhouse inoculation with anthracnose the F_1 were found to be resistant, that is, resistance was dominant over susceptibility, and segregation in the F_2 and in the F_1 back-cross suggested that a single factor pair for resistance or susceptibility was involved. Layton used the lesions produced on the hypocotyl of young melon seedlings as his index of susceptibility or resistance, and showed further that leaf infection did not take place if the temperature was 15° C. or lower, while above 18° C. the infection was severe. Plants inoculated and held at the lower temperatures developed lesions later on the hypocotyl at ground level. Segregating F_2 plants were grown in the greenhouse, and those individuals resistant to anthracnose were transplanted to Fusarium wilt-infested soil. Surviving plants were then crossed on the wilt-resistant Klondike, Stone Mountain and Improved Kleckley Sweet No. 6 to improve the quality. In 1947 the Iowa station released their variety Black Kleckley, a cylindrical melon with very dark, almost black rind, and white to light tan seeds, resistant to anthracnose and Fusarium wilt. Unfortunately the variety was re-

leased while still segregating for seed color, and seed lots received at Leesburg showed a low percentage of black seeds. In Florida in 1947 the melon was late to mature, later than Blacklee, of good quality and showed a fair degree of resistance to anthracnose; its wilt resistance was not tested. The Black Kleckley is too small, 14–18 pounds, to serve as a shipping melon for Florida or Georgia.

In 1936 Layton sent four of his anthracnose-resistant melons with African ancestry to Walker at Leesburg, who grew the strains on wilt-infested soil. By 1941 there were a number of strains showing high resistance to wilt, differing in such physical characters as shape and size of melon, but all possessing light tan colored seed. Their quality was only fair, but they were anthracnose-resistant. In 1942 six crosses were made at Leesburg to combine this resistance with the wilt resistance and high quality of the Blacklee and other unnamed melons of this type, and with an unnamed wilt-resistant and high quality but undesirably small melon of the Cannon Ball type. The F_1 received preliminary testing for anthracnose resistance in the greenhouse in the late summer and fall of 1942, and findings were rather unexpected for plants seemed to be susceptible to the disease[4]. In 1943 and 1944 there was no plant pathologist at the Leesburg laboratory, and the progenies of the six crosses were studied in the field on Fusarium-wilt-infested land and purity of the lines maintained by selfing, but they received no further greenhouse testing for anthracnose resistance until after the 1945 growing season when the writer inoculated strains that had been selected, 41 in number. No resistance was found. The parental stocks carrying the anthracnose resistance also were tested and found to continue to possess the resistance described as "R+" by Layton (15). At that time it was considered strange that disease resistance was lacking, and this lack was attributed to the type of selections made in the field in 1943 and 1944 when quality had been emphasized while resistance was neglected. Since only one of the 41 lines has proved to be as early as the Blacklee, the others have been discarded.

The crosses made in 1942 to combine anthracnose resistance and the high quality of the Blacklee were repeated in 1946, and, in addition, several lines resistant to anthracnose and Fusarium wilt, received from the U. S. Regional Vegetable Laboratory, S. C., were employed as parents. The F_1 were grown in the field in the summer and early fall at Leesburg, on land treated with D-D mixture (20) to eradicate the root-knot nematode, *Heterodera marioni* (Cornu) Goodey. All plants showed susceptibility to anthracnose, which was contrary to the aforementioned report (15) that resistance was inherited as a dominant character. F_2 seed was planted in the field in 1947 and anthracnose was abundant; little resistance appeared, and inoculation in the greenhouse (August and September, 1947) showed not only that all lines were highly susceptible to anthracnose, but also that all parental material, formerly resistant, was now susceptible. Further tests, which will be reported in detail elsewhere, indicate the existence of more than a single physiological form of *Colletotrichum lagenarium*.

Dolan (7) studied a melon variety, the McCrea, referred to as "anthracnose resistant", which he used as parental material in inheritance studies on two melon anthracnose diseases caused by *Colletotrichum lagenarium* and *Marssonina melonis* n. sp., respectively. The McCrea was resistant to *Colletotrichum* but susceptible to *Marssonina*, and all plants of the segregating backcross and F_2 progenies had medium-to-severe infection with *Colletotrichum*. Most of the plants in each progeny were severely affected, and no definite resistance ratios were dis-

4 Verbal statement to the writer by Dr. M. N. Walker, December 1947.

cernible. If resistance were dominant, as Layton (15) believed, these results are not easy to understand.

Mosaic. Porter and Melhus (30) found that edible watermelon varieties are highly resistant, if not immune, to mosaic, but that the red seeded citron is susceptible. They crossed the inedible Kafir, White Seeded, Majorta, Mammoth White, Stock and Preserving Citron with five watermelon varieties and found that the F_1 were highly susceptible to the disease. When White Seeded and Kafir were used as parents the F_2 were less susceptible than when the others were the parents. Walker (47) recorded the first natural occurrence of mosaic.

Root Galls. Walker (50) found galls on the roots of citron plants and also on the F_1 of crosses of watermelon on citron. No causal agent was associated with the enlargements, and their nature is imperfectly understood.

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Utilization Abstract

Chemurgic Utilization of Wood. Wood consists of about 80% cellulose and 20% lignin, and the various processes employed in the conversion of it into a variety of products may be summarized as follows:

Paper Pulp: subjection of wood to the action of chemicals, such as sulfite or soda liquor, that react with and dissolve the lignin but have no effect on the cellulose fibers, produces the fibrous pulp.

Sugar and Alcohol: chips, sawdust or shavings of almost any species of wood subjected to the action of steam at 150 to 200 pounds per square inch pressure while dilute sulfuric acid solution is percolated through the bed of finely divided wood for three to four hours results in the cellulose of the wood being converted into hexose and pentose sugars, principally glucose, or dextrose, the sugar normally present in corn syrup and honey. This process, sometimes called "wood saccharification", since it results in the formation of sugars, is essentially hydrolysis of cellulose under the catalytic influence of sulfuric acid. "The acid solution containing sugars produced by the action of water on the cellulose is continuously removed from the digester. At the end of the reaction the digester contains the lignin residue from the wood, which is washed free of sugars with water. These washings are added to the sugar solution removed during the digestion, and this solution is then treated to neutralize the acid, after which it is fermented to produce alcohol.

"In processing a ton of wood in this manner about 1,000 pounds of sugars and 600 pounds of lignin will be obtained. The sugars can be converted by fermentation into about 50 gallons of alcohol and 375 pounds of yeast fodder. The latter contains 55 to 60 per cent protein that can be used as the sole source of protein in animal feeds. The ethyl alcohol produced in this manner is the same that is obtained from fermentation of grain or molasses".

Lignin. "The lignin residue from the hydrolysis process is compounded with various synthetic resins to produce moulding compounds from which plastic articles . . . are made. Fillers, such as wood flour, have been employed for this purpose, but by using the lignin residue from the hydrolysis process, the amount of synthetic resin (which is the more expensive ingredient of the moulding compound) can be materially reduced because the lignin filler itself acts as a resin extender". Such lignin plastics are suitable for battery boxes and other acid-containing articles. Because the lignin thus used "is a by-product from the production of the main product, alcohol, its price can be much lower than that of many of the other plastics manufactured at the present time".

"Plastics are also made from the lignin extracted from wood in the pulping process", and "some of the other uses to which lignin from pulping process has been put are: a) production of water-resistant adhesives for bonding plywood veneer, by reacting the lignin with amines or phenols; b) as corrosion inhibitors; c) as a flotation agent; and d) in production of ion exchange resins for water softening".

Improved or Transmuted Wood. By cutting wood into "veneer, and reassembling the thin sheets so that in every other layer the grain is at right angles to the direction that it is in the layers adjacent to it, and sealing the sheets to one another by applying glue between the surfaces, a panel is formed which does not shrink and swell like ordinary wood as humidity varies. The tendency of a layer to swell in width is restricted by the adjacent layers whose grain runs in the opposite direction. Such a construction has come to be known as plywood".

The original non-water-resistant glues used in making plywood have been replaced by water-resistant synthetic resins, the most widely used of which is phenolformaldehyde, or phenolic resin. "This resin is made by

reacting phenol (carbolic acid) with formaldehyde (embalming fluid). To produce this resin the two ingredients are mixed in the desired proportion, a small amount of ammonia or sulphuric acid is added to catalyze or initiate the reaction, and the mixture heated. As heating is continued the reaction forms a thick, syrupy, amber colored phenolic resin. If this resin is heated for a time at about 300 degrees F it sets up into the hard, insoluble resin or plastic known as Bakelite.

"In making up plywood with phenolic resin the syrupy liquid just described is either spread on the surface of the plies with a glue spreader or strips of tissue impregnated with the syrupy resin are laid between the plies and the assembly placed between the platens of a hydraulic press at about 300 degrees F. and a pressure of 100 to 200 pounds per square inch applied. The pressure causes some of the resin to flow from the glue line into the wood to a depth sufficient to give a very strong bond when the heat has set it up into the hard product Bakelite; in fact the finished glue line is stronger than the wood itself".

"Synthetic resin bonded plywood was extensively used in the recent war for the production of aircraft, boats, and other military equipment as well as in buildings such as aircraft hangars and warehouses. By laminating and bonding with synthetic resins, immense integral beams of complicated design can be built up from relatively small pieces of wood. Wherever this resin bonded plywood has been used with proper regard to its limitations its performance has been excellent".

But water-proof glue lines do not mean water-proof panels, for, while the alternate cross-grain construction of such panels restricts shrinkage and swelling, changes in moisture content develop such tremendous stresses in the sheets of wood that the panels break down, not at the glue lines but in the wood itself. This has been overcome by impregnating the sheets of veneer with the resin—not merely applying the resin as a coating between the plies—and then converting the sheets into a hard plastic by heating. Wood built up of such impregnated sheets is known as "Impreg".

"Subsequently it was found that wood completely penetrated by the resin could be compressed to as little as one-third of its original thickness and when the resin had set, the panels could be removed from the presses without losing their highly densified condition, even when placed in boiling water. . . . The resin impregnated, laminated wood material that has been made super-hard by compressing it permanently to less than its natural thickness is called "Compreg". It will take up less than five percent water even when boiled in it".

"By means of resin impregnation and densification even inferior grades of wood can be made to surpass any of the highest grades of natural woods in strength and other properties. One field in which resin impregnation is used to impart special properties to wood is that of the textile industry. Heretofore these special properties have been obtained by selecting certain species of wood that through experience had been found to possess them. For example the bobbins used in the textile industry have largely been made of dogwood or hard maple, but because of the slow rate of growth of these species the available supplies are being rapidly depleted. By use of resin impregnation techniques it has been found possible to impart the desired properties to other species of wood whose growth rate is sufficiently rapid to assure a continuing supply".

"So far Impreg and Compreg have found use in war materials in such applications as spars, aircraft carrier decking, antennae masts, panels, bomb bay doors, expendable wing tanks, pontoons, propellers, and instrument panels in aircraft, and special applications for decking and paneling in boats. Peace-time uses include such items as mar-resistant and waterproof table tops, high

grade furniture, spindles and bobbins for textile plants, electrical panels, and handles". (M. S. Hudson, *Chemurgic Digest 7 (8): 7. 1948*).

Hyoscine and Hyoscyamine. "One plant drug which was in short supply in all Allied countries during the recent war was the alkaloid hyoscine. This drug, which in larger doses is beloved by fiction writers as an obscure killing agent, was previously mainly used in association with morphine at childbirth and as an hypnotic agent in certain mental disorders. As the war progressed the demand for hyoscine rose to unprecedented levels as it was found to be of great value in the treatment of "bomb shock" and other war neuroses. Extensive experiments made in connection with the problem of motion sickness in seaborne troops revealed that hyoscine was the best drug available for alleviating the condition, and it was used freely from the Normandy invasion onwards.

"The small pre-war demand for hyoscine was easily met by reclaiming the alkaloid from the mother liquors after hyoscyamine (the chemical source of atropine) was extracted from the leaves of the belladonna plant *(Atropa Belladonna)*, or directly from other species of the Solanaceae, in *Datura* or *Hyoscyamus*, in which it occurred in small amounts. However, practically all the raw plant material had come from the European continent, and this, combined with the increased demand, resulted in an acute supply problem.

"It had long been known that the leaves of a tree of the potato family (Solanaceae), indigenous to Australia and New Caledonia, popularly known as "corkwood" on account of its spongy cork-like bark, and scientifically as *Duboisia myoporoides*, contained a complex of alkaloids with physiological effects similar to those of atropine. As a result of the wartime emergency, interest in the species, as well as in that of a second member of the genus, *D. Leichhardtii*, was re-awakened. The Australian Council for Scientific and Industrial Research, working in co-operation with the Universities of Sydney and Melbourne, began an investigation and discovered that not only did hyoscine occur in the leaves of certain types of both species, but that it did so in concentrations four or five times as great as had been found in any other plant. As a result of intensive laboratory and field tests a commercial firm was soon producing hyoscine in adequate quantities and at a lower price than had previously been thought possible. During the war emergency, more than 7,000 ounces of the drug were produced in Australia from this new source. This is said to exceed the total amount which had previously been produced in the world.

"There are only three species of the genus *Duboisia*, none of which occurs beyond Oceania. The third species, *D. Hopwoodii*, is a desert tree confined to the arid interior of the Australian continent which, strangely enough, does not carry the hyoscine-hyosciamine group of alkaloids, but is rich in nicotine and nor-nicotine. *D. myoporoides* is a subtropical species having a scattered distribution along the eastern coast of Australia, whilst *D. Leichhardtii* is confined to a relatively small section of the southeastern highlands of Queensland. The latter species in particular is not plentiful and the wartime demand made such heavy inroads upon the natural stands that at one stage it was feared that it might become extinct. The characteristic of vegetative regeneration after cutting back, which is common to both species, has undoubtedly been one of the principal factors in their preservation. Neither species is strongly competitive and both are readily crowded out by other trees. They have a very scattered distribution and are generally found as isolated trees or small groups in forest clearings or along river banks. In certain areas, plants of *Duboisia* are among the first to establish themselves after forest fires, but they ultimately give way to the more permanent secondary flora.

"The species have hitherto only been known in the wild state but successful methods of cultivation have now been devised and there seems no reason why the species should not take their place alongside the regularly cultivated drug plants such as digitalis and belladonna. Although their natural habitat is subtropical, they have shown a wide range of climatic adaptation under experimental conditions and have been found to survive quite severe frosts. Under good conditions seedling trees have been observed to increase in height at the rate of 1 inch per day for periods as long as a month.

"The method of cultivation adopted is based on the maintenance of the plants as bushes rather than trees. They appear to maintain their perennial nature when trimmed regularly, and yields on the order of one ton of dry leaf per acre per year have been obtained. Leaf grown under such conditions contains at least as great a quantity of alkaloids as that collected from wild stands.

"Selection and testing of different types found within the species has gone forward concurrently with the cultivation trials. Although the genetic-environmental relationships of the alkaloid complex are somewhat involved, it has been possible to isolate types which yield hyoscyamine under any environmental conditions and others which yield hyoscine in most circumstances. In many cases the alkaloids are present together, the proportion of each depending on the environmental conditions and the genetic nature of the material.

"The rapid growth of *Duboisia* and its adaptability to cultivation, combined with a very high percentage of alkaloid in the leaves, should insure its becoming the principal world source of hyoscine, and possibly also of hyoscyamine. Seed has been sent from Australia to other countries, including the United States of America, and it is expected that the species will ultimately be cultivated successfully wherever conditions of soil and climate are suitable throughout the world". (K. L. Hills, *Jour. N. Y. Bot. Gard.* 49: 185. 1948).

Cocona. An almost unknown but highly promising edible fruit of the upper Amazon is the cocona, *Solanum hyporhodium*. Credit for its introduction from the wilderness to the garden is due staff members of the Tingo Maria Experiment Station of Peru where attempts are being made to improve it through selection and hybridization with several closely related species, especially *S. quitoense*, *S. hirsutissimum* and *S. hirtum*.

"Cocona plants grow to a height of four or five feet, having a coarse sprawling shrublike growth with very large leaves. They are completely spineless and have prospered in full sunlight at Turrialba, Costa Rica.

"The ovoid fruits, which are suggestive of large red or yellow apples, are held in compact clusters close to the trunk and branches. The plants are heavily productive, ofttimes being loaded down with from 40 to 60, or more, pounds of fruit. About seven months are required from planting to first harvest. Ripening may then continue for several months.

"Upon reaching maturity, cocona fruits turn from the earlier bright-yellow to deep-red or burnt-orange color and are then most attractive. At this stage the peachlike fuzz which is typical of this tribe of edible large-berried fruits of the genus *Solanum* is easily brushed off, leaving a clear and blemish-free skin.

"The flesh and inner pulp are of a pale-cream color throughout, a fact which readily distinguishes this fruit from its two nearest relatives, the naranjilla and lulita, the pulp of which is a translucent green color.

"Although the flavor of uncooked coconas is agreeable, the pulp is distinctly acid, and they are not recommended for eating out of hand. When peeled as an apple and used entire for making preserves, pies and sauces, the product might be compared with that of an apricot, pineapple or gooseberry. Cocona marmalade and preserves are a rich trans-

parent orange in color, and their tart and spicy flavor is both delicious and distinctive. One can safely say that there are few fruits available to the warm humid sections that can equal or surpass the better forms of this fruit for such culinary uses".

"*Solanum quitoense* is the plant known and cultivated as 'naranjilla' and 'lulu' in the more northern Andean regions of South America. In the highlands of Ecuador and southern Colombia the naranjilla is highly prized as a juice fruit and constitutes an important economic commodity. It is found wild from Costa Rica to Peru.

"Unfortunately, this species has seldom prospered in other regions, owing largely to sensitivity to environment. At Turrialba, Costa Rica, the naranjilla must be grown in half shade and has not relished high temperatures or dry soils. The ripe fruits are aromatic and acid though low in sugar. Keeping or shipping qualities are only fair.

"The lulita, of the species botanically known as *S. hirsutissimum,* is occasionally found in the warmer and dryer parts of Costa Rica and Panama and as far south as Peru. It is little known either horticulturally or botanically. At Turrialba it prospers in full sunlight and has withstood considerable drought. The fuzzy or hairy fruits are about the size and shape of a hen's egg and when ripe show a rich orange color. The plants are extremely spiny.

"With full maturity, fruit of the better lulita selections is quite agreeable, being aromatic, juicy, and tart with a flavor suggestive of plums. With certain refinements, this species could become truly desirable for eating out of hand. In general, the fruits indicate a higher sugar content than do either the cocona or the naranjilla, although they are typically quite seedy. The better strains of this species might contribute admirably to a breeding project in way of fruit and cultural assets.

"Preliminary efforts to hybridize these species have resulted in little encouragement to date. Fruit setting from pollinated flowers has not been too difficult to accomplish, although the seeds obtained generally have been poorly developed and in all cases have failed to germinate. The mere fact, however, that in a few instances plump seeds were formed affords some hope that ultimate success may be possible.

"In any event, a safe assumption is that even in its present unimproved state the cocona is a permanent acquisition as a valuable horticultural plant. Anyone who has seen it, or has eaten the appetizing culinary products made of it, will testify to that. The possibilities of its culture in temperate climates must yet be determined". (*J. L. Fennell, Foreign Agriculture* 12: 181. 1948).

Cedarwood Oil. *Juniperus virginiana,* naturally distributed east of the Rocky Mountains from Canada to Florida, has for many years been the chief source of cedarwood oil for the aromatic trade. For about 18 years, however, Texas, or Mexican, cedar (*Juniperus mexicana*) has also been a source of cedarwood oil which has appeared on the market intermittently in a crude state without any refining. This species, a usually crooked and irregular tree up to 20 feet in height, inhabits the rough limestone hills of central and west Texas, originally covering about seven million acres. Clearance work to increase grass production has reduced the area with trees to about three million acres. The few limbs of this species "that are straight have been used to some extent for fences and house blocks, but these are the only uses that have ever been found for this cedar with the exception of oil. These trees are too crooked and irregular for sawing and the wood checks after it has been exposed to the atmosphere".

The only cedarwood distillation plant in the *Juniperus mexicana* area, on the Guadalupe River about three miles north of New Braunfels, Texas, has been bought by the Southwest Cedar Oil Company and is now grinding about 50,000 pounds of cedarwood daily for the production of oil. The com-

pany has also established a laboratory to explore all possible uses of the oil.

"For oil distillation the wood is usually cut by Mexicans on a contract basis by the cord and is stacked in the cut-over area to dry. When dry, the wood grinds and distills better than when green. It is usually seasoned for 90 days, but is not harmed if left outdoors for a year or two.

"When ready to use, the wood is dumped into a conveyor which carries it to the wood hog or chipper and thence into the hammer mill which reduces the size of the chips to 6 mesh. The chips are collected in a cyclone. A conveyor then dumps them into the top of a still. The stills are 7 x 10 feet and will hold about 5000 pounds of grindings.

"Steam is fed into the bottom of the still and is distributed so as to come up uniformly through the mass of wood. After the distillation is finished, the wood is dumped into a triangular hopper at the bottom and is carried out by conveyor, either to the boiler firebox or to the wood stack outside. The boiler uses about 50 percent of the wood residue.

"The steam picks up the volatile oil and carries it to the oil house where it is separated from the water in condensation. The oil at this stage is crude and dark red. It is shipped to the fractionating plant in San Antonio.

"Plans for distillation of the leaves have not been put into effect as yet. The leaves carry about 1¼ percent crude oil, of which about 40 percent is gum camphor and the other 60 percent a very pungent leaf oil. The camphor has been tested and apparently is chemically identical with Formosa camphor but none of the leaf oil or camphor has ever been put on the market. Laboratory work has been carried to a point where all information has been worked out for a pilot plant for the separation of the camphor from the leaf oil and it is planned to get this in production within the next few months.

"After the crude oil reaches the fractionating plant at San Antonio, the oil is run into a high vacuum still for first processing. Although laboratory tests have broken down the crude oil into 27 separate fractions, this quantity would be excessive for commercial production at the present time. Accordingly, only four separations are made in the crude: the white oil, pseudo cedrol, crystalline cedrol, and cedarwood tar. These products form the basis for the other products that are made from the oil by blending, redistilling, cracking, synthesizing, or recrystallization, depending on the product that is desired. There are 16 different oils and other products produced from these four basic fractions, and each of the oils and other products has its own characteristics.

"Cedrol content of the crude oil is very high and the extreme stability of the cedrol and the pseudo cedrol offers possibilities for fields where an alcohol of this type would prove advantageous, some of which have been determined. Research is being continued on the cedrols as well as the hydrocarbons.

"Most of the oils and other products thus far developed have been for the aromatic field. This group includes eleven oils, pseudo cedrol, crystalline cedrol, recrystallized cedrol, cedarwood tar oil and cedarwood tar.

"These products have proved to be of value for aromatic perfumes, soaps, a fungicide for leather, activator in insecticides, carbon remover for gas engines, furniture and floor polishes, moth proof clothing bags and cabinents, lubricating greases, printing inks, carbon paper and typewriter ribbons".

Other uses and potential uses of Mexican cedarwood oil include: *a*) fungus inhibitor in chrome tanned leather, *b*) leather preservative, *c*) moth-proofing spray, *d*) flotation agent. And the ground wood, after being steam distilled to extract the oil, is valuable as a conditioner of alkaline soils. For this purpose the ground wood has been impregnated with minor elements. (C. Pool, *Chemurgic Digest* 7(7): 7. 1948).

Wormwood. "Time was when the wormwood plant (*Artemisia Absinthium*) was used chiefly for the preparation of absinthe—a green, bitter, aromatic liqueur that came to be known as one of the most notorious of all alcoholic beverages. Today, however, the only known use of wormwood in the United States is for its yield of an oil that is one of the principal ingredients of certain external liniments to warm the muscles instead of assuaging the stomach.

"Practically all of this chemurgic crop that is produced in this country is grown in St. Joseph, Cass, and Allegan counties in Michigan, and in St. Joseph county in Indiana. Much of the crop is purchased by a single company, W. F. Young, Inc., of Springfield, Mass., manufacturers of 'Absorbine' preparations.

"In an unusual arrangement for production and purchase of a farm crop, the Young Company contracts for its purchases several years in advance. The contracts guarantee the farmers who sign a fixed price for all the oil they can produce on a specified acreage.

"Growers usually get a crop that yields from 15 to 20 pounds of oil per acre, and some have gone as high as 35 pounds. The usual gross income at present prices is from $90 to $120 per acre, but unless chemists discover additional uses, the prospects for expanded acreage are relatively light.

"Wormwood is a perennial that usually lasts for seven to 10 years from a single planting. It is originally grown in beds, and is transplanted with the help of mechanical setters.

"The oil of wormwood is obtained by steam distillation. On reaching maturity, the plants are cut and hauled to a still. There they are tightly packed in tubs or vats, and cooked for one to two hours in live steam.

"The oil content is carried into the steam overflow from the vats, thence through a condenser where the oil is separated from the water. The residue is usually spread over the freshly cut fields as a mulch to keep down weed growth.

"The Young Company estimates from 2300 to 2900 acres of wormwood is grown in this country. One of the largest producers is T. C. Carter & Son, Vandalia, Mich." (*Anon. Chemurgic Digest 8(1): 11. 1949*).

Cottonseed. At present 4½ million tons of cottonseed are produced annually in the United States, over 40% of the world's production. Cottonseed ranks fourth in value among the nation's crops, and its value combined with that of staple cotton, places cotton very close to corn, the leader.

Cottonseed is the principal source of protein feed for the South, obtained as a by-product of oil extraction, and considerable research in its processing and byproduct utilization is being conducted at the various State Colleges of the South under sponsorship of the Texas Cotton Research Committee, and at the Regional Laboratories of the U. S. Department of Agriculture.

"Corn is now processed to obtain pure starch, dextrin, sugar, syrup, zein, oil and inositol. Cottonseed contains an even greater wealth of chemicals which are not as yet separated in pure form to obtain their greatest value.

"At present cottonseed is processed essentially by the hydraulic press method. The short fibers left on the seed by the cotton gin are removed by linter machines, similar to gins, which pull the fibers off with rotating saws. Hulls are next removed by disc mills or bar hullers and separated from the meats by screens and air separation. The meats are rolled into flakes, cooked for about an hour at 240° F., and the oil then squeezed out by hydraulic presses. In some instances the oil is squeezed out by screw expellers which force the meats at high pressure through slotted tubes.

"Cottonseed linters are sold as raw material for rayon, gun cotton, and for upholstering. The hulls are used mainly for livestock roughage although their consumption for the manufacture of furfural has increased since the discovery of a method for converting furfural to nylon.

"Cottonseed is the standard source of protein feed for the southern farmers. It is of excellent quality and highly palatable to animals. It is sold for direct use or blended into mixed feed. The cottonseed oil is usually sold in the crude form to the vegetable oil refiner who makes it into shortening and margarine.

"The most important development in cottonseed has been the use of solvent extraction methods. Solvent extraction has proved its value in the soybean industry where the capacity of solvent extraction plants has tremendously increased. However, its use in processing cottonseed in this country is so new that its success has not yet been established.

"The first solvent plant for cottonseed in this country was completed at Wilson, Arkansas, less than a year ago. Since then plants have been constructed for cottonseed extraction at Helena, Ark., Memphis, Tenn. and Abilene, Tex. As yet, practically no technical information on the operation of these plants is available".

The standard solvent used is a petroleum fraction containing essentially n-hexane. The oil is recovered by evaporation of the solvent which in turn is condensed and reused. Other solvents, such as alcohols and chlorinated hydrocarbons, are being considered. Isopropanol, the ordinary rubbing alcohol of the drug store and easily produced from petroleum cracked gases also appears to be a suitable solvent, for, in addition to removing the oil it also dissolves gossypol and related substances which when left in the meal are toxic to certain animals. Gossypol is rendered inactive by cooking the meats before pressing, but cooking has been shown to be detrimental to the protein in the meal.

Oil, fatty acids and sugars can be separated from the isopropanol extract. The sugar is non-sweet, normally indigestible raffinose which can by hydrolized into simpler, sweet, digestible sugar. The oil "contains appreciable quantities of three other valuable substances: the phosphatides, tocopherols and sterols. These substances are now wholly or partially wasted in processing. Lecithin is the commonly known phosphatide. It is now produced commercially as a by-product in the soybean extraction process, and has a wide variety of uses. The tocopherols are known as Vitamin E and are prepared by molecular distillation of the oils. In addition to their vitamin uses they are valuable antioxidants for preventing rancidity in fats. Cottonseed is one of the richest of the common oils in tocopherol content.

"The sterols are chemically inert and do not contribute to any important property of the oil. However, they constitute starting materials for synthesis of sex hormones and are used for preparation of Vitamin D.

"A ton of cottonseed will contain 6.5 lbs. of lecithin, 5.4 lbs. of sterols, and 0.4 lbs. of tocopherols. The latter two substances have a very high commercial value in purified form. Alpha-tocopherol is quoted at $340 per lb. From 10 to 15 lbs. of gossypol are contained in a ton of cottonseed. As yet gossypol has no commercial value; however, if it were isolated in pure form, uses would surely be found. It is an excellent antioxidizing agent.

"The lecithin, vitamin E sterols, and gossypol are all obtained in concentrated fractions by the isopropanol extraction process for cottonseed oil. Purification of these substances should not be difficult, and they can then be produced as new marketable products from cottonseed. In addition, the higher grade meal, freed of its impurities, will be a source of flour for human consumption and commercial protein for fiber and plastic manufacture". (W. D. Harris, *Chemurgic Digest 7(11): 9. 1948*).